Electrical Engineering

January
1940

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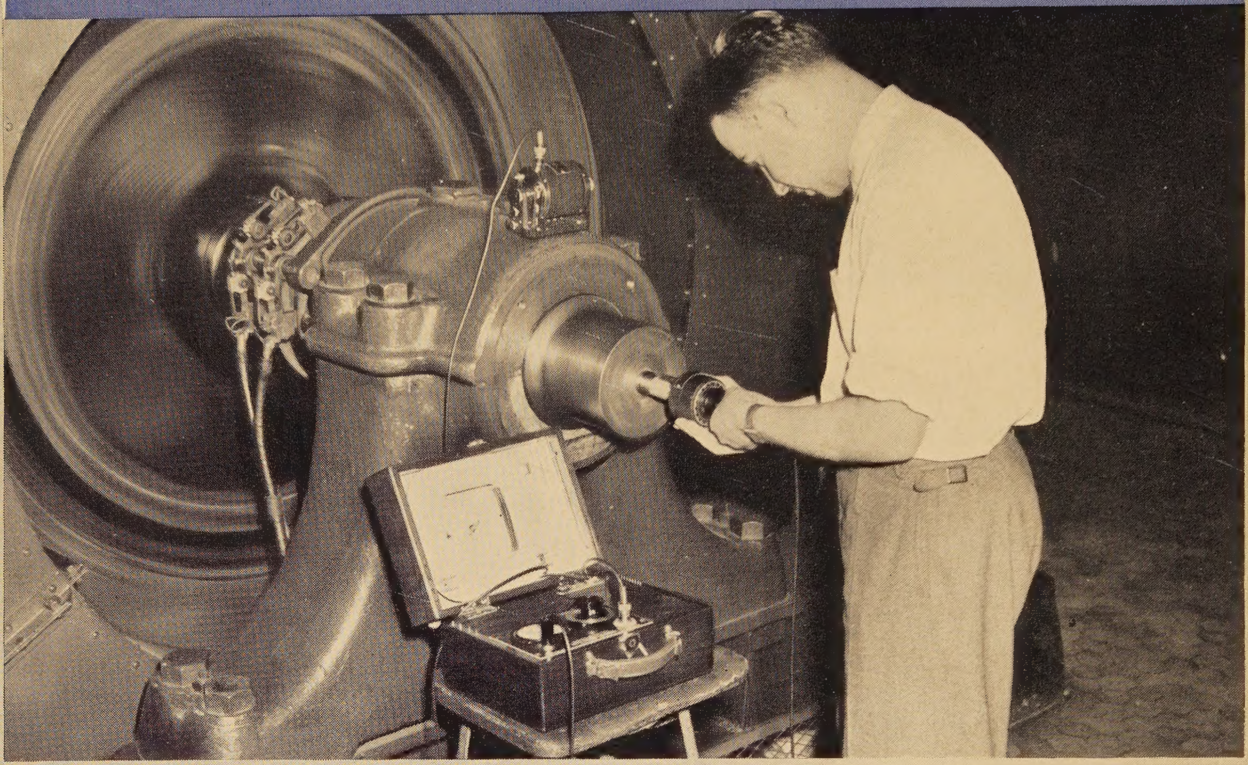
To Measure—BALANCE

ELECTRICALLY



HOW simple would you say it is to balance a 50-ton alternator rotor moving at 3600 rpm until its vibration is less than three ten-thousandths of an inch—or one-tenth the diameter of a human hair? Not very, you say? Well, a little while ago you may have been right. Today you're wrong.

For while heretofore the balancing of large rotating machines was a long, drawn-out procedure, perhaps requiring the removal of the rotors from the machines, now there is a portable G-E instrument that does the job simply, quickly, and under actual operating conditions. And on a 20,000-kva synchronous condenser, for example, balance can be achieved with as few as three runs—which is a far cry from the 100 to 170 trials which were frequently necessary before.

In simple terms, the balancer consists of a hand-held sine-wave alternator, a vibration pick-up, and an instrument. These provide the essential measurements, which are made both before and after trial weights have been placed in chosen balancing planes. By interpretation of the facts thus obtained, almost perfect balance of the machine can be achieved.

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HEADQUARTERS FOR ELECTRICAL MEASUREMENT

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Electrical Engineering

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The Cover: Overseas office of the American Telephone and Telegraph Company, New York, N. Y. Telephone connections from the United States to 74 other nations have been established, according to an article in this issue by an AIEE past president (pages 3–11)

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High Lights

Two-Pole Generators. The unequal mechanical rigidity of the rotor body on the two major axes and unequal magnetic forces on any two major axes of the stator core produce vibrations in two-pole generators that become of increasing importance in 3,600-rpm units of relatively large capacity; the disturbing force may be eliminated or the vibration restricted to isolated parts (*Transactions pages 30–4*). Critical speeds of rotors may be predetermined analytically and stresses determined by the photoelastic method; control of bearing lubrication promises increased efficiency (*Transactions pages 51–6*).

Winter Convention. More than 80 technical papers are scheduled for presentation in the 18 technical sessions and 9 conferences of the AIEE winter convention, to be held January 22–26, 1940, at New York, N. Y. Presentation of the Edison and Hoover Medals, and of the Alfred Noble prize, a popular demonstration lecture, the annual smoker and dinner-dance, and an unusual group of inspection trips are other features of the convention (*pages 37–41*).

Insulation Research. Continuing its unique position of effectively bringing together both scientific and "practical" groups interested in the general subject of electrical insulation, the Conference on Electrical Insulation of National Research Council recently held its 12th annual meeting. The 26 progress reports presented at its four technical sessions reflected the latest advances in insulation research (*pages 33–6*).

Power Generation. The use of 3,600-rpm high-pressure high-temperature hydrogen-cooled turbine-generator units of large size is the most important advance in electric-power generation during the past six years, according to the current progress report of the AIEE committee on power generation. In the hydroelectric field, activity has centered largely in governmental projects (*pages 12–22*).

Electrical Insulation. Those who have not had an opportunity to follow closely the progress in the field of electrical insulation, but who would like to obtain a general view of the present status of the art, may be interested in a review of the advancements achieved by the physicist, the chemist, and the electrical engineer—the triple alliance in electrical insulation (*pages 23–32*).

Section Activities. In recognition of effective services to the Institute, the AIEE national membership committee lists in this issue the personnel of the membership committees of all 67 of the Institute's local Sections (*pages 52–3*). Some of the current activities reported by the various Sections are reviewed by a member of the Sections committee (*page 51*).

Transcontinental Telephony. "In its journey during the last quarter of a century telephony has crossed several thresholds, but, even so, the journey may be in its early stages," says a noted AIEE past president in reviewing the progress achieved since 1914 when the first transcontinental telephone conversation transpired (*pages 3–11*).

Machine-Tool Equipment. Electrical equipment for machine tools has helped improve the performance of the tools, but motors and control devices should have greater reliability and be more suitable for application on different voltages and frequencies in order to compete with mechanical and hydraulic control (*Transactions pages 18–24*).

Air Circuit Breakers. Development of air circuit breakers has paralleled the growth of power systems since the first knife-switch device was used about 1885. Modern low-voltage air circuit breakers with a new type of arc interrupter have interrupting ratings up to 80,000 amperes at 600 volts alternating current (*Transactions pages 24–30*).

Hydrogen-Cooled Generators. Hydrogen offers several advantages as a cooling medium as compared with air in electrical machines, and is used in many generators operating at 3,600 rpm. Suitable shaft seals, cooling means, and control system for gas must be provided (*Transactions pages 11–17; 35–50*).

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Carrier-Current Losses. The carrier-current channel for supervisory control on the Boulder Dam-Los Angeles transmission lines was found to have higher than calculated losses, and to require special circuit designs to suppress interference from static, corona, and arcs (*Transactions pages 4–10*).

D-C Amplifier. A high-gain d-c amplifier for recording nonrecurrent biologic phenomena on a cathode-ray tube, using radio-receiver-type components, has a maximum voltage amplification of 6×10^6, and requires only moderate battery voltages (*Transactions pages 60–4*).

Turbine-Electric Drive. A form of drive in which a steam turbine is coupled both mechanically and electrically to a textile "range," or group of co-ordinated machines, provides variable speed and flexibility (*Transactions pages 57–60*).

Textile Machinery. Tests have been made to establish the characteristic power requirements and derive an empirical formula for horsepower for spinning machines (*Transactions pages 1–4*).

Coming Soon. Among special articles and technical papers now undergoing preparation for early publication are: an article embracing the essential substance of the lecture on atomic disintegration to be delivered at the AIEE 1940 winter convention by Nobel Prize Winner Enrico Fermi; an article tracing recent trends in steel-mill electrification by A. F. Kenyon (A'24); an article discussing the role of science in the electrical industry by M. W. Smith (M'36); a paper continuing a series of reports of a lightning investigation on transmission lines by W. W. Lewis (F'38) and C. M. Foust (M'31); a paper on the transformation theory of general static polyphase networks by L. A. Pipes (A'37); a paper describing methods of sensitive ground protection for radial distribution feeders by L. F. Hunt (F'38) and J. H. Vivian (A'34); a paper discussing the anomalous behavior of the moving systems of single-phase a-c watt-hour meters at no load by F. C. Holtz (M'25); a paper describing the testing of distribution arresters by Herman Halperin (M'26); a paper on surge-voltage breakdown characteristics for electrical gaps in oil by R. W. Sorensen (F'19); a paper describing capacitor relay timing in industrial control by Carroll Stansbury (F'38) and T. B. Jochem (A'32); a paper on the high-capacity "hydro-blast" circuit breaker for central-station service by W. F. Skeats (M'36) and W. R. Saylor (A'38); a paper describing a new time standard by H. E. Warren (A'02); and a paper on the transient and steady-state performance of potential devices by E. L. Harder (A'30), P. O. Langguth (A'28), and C. A. Woods, Jr. (A'37).

Subscriptions—$12 per year to United States, Mexico, Cuba, Porto Rico, Hawaii, Philippine Islands, Central and South America, Haiti, Spain, Spanish Colonies; $13 to Canada; $14 elsewhere. Single copy $1.50. ¶ Address changes must be received by the 15th of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge. ¶ ELECTRICAL ENGINEERING is indexed annually by the Institute, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index*; abstracted monthly by *Science Abstracts* (London). Copyright 1940 by the American Institute of Electrical Engineers. Printed in the United States of America.
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A Quarter Century of Transcontinental Telephony

A review of the significant developments in long-distance telephony since the first transcontinental telephone conversation in 1914

FRANK B. JEWETT
FELLOW AIEE

AS A TOPIC I have chosen the epoch of transcontinental telephony because it was 25 years ago last July that the first transcontinental circuit carried its first conversation, and it is 25 years ago this January that the first transcontinental line, which consisted of three circuits, was opened for public use. My choice, however, is based upon much more than a mere desire to commemorate a now far-off event, propitious though such a gesture may be. I hope that I can portray this early telephone line for what it was in fact—the progenitor of much that has taken place in the last 25 years in a very active sector of electrical engineering. It marked the dawn of a new era in electrical communication.

As we review the history of this period, we witness new physical appliances recasting not only the technological side of a business but its traffic and commercial aspects as well. I hope to make clear the interplay of technological and economic factors over a considerable period of time to the end that copper and iron in huge quantities have been replaced by minute electron streams *in vacuo;* further that the attenuation of telephone currents, once the epitome of the telephone engineer's troubles, can now be pushed to levels hundreds of times higher than the early limit before it becomes comparable with the other economic factors involved.

In any general survey of the changes and improvements that have altered the art of telephony during a period of time or have stemmed from the successful solution of a specific problem, one must always have in mind the ultimate objective of commercial telephony. This objective is simply stated; the attainment of it, even approximately, is by a long hard road. From the day when men of vision realized the potential possibilities of Bell's invention, the ultimate technical objective has been a service at once so extensive and adequate that anyone, anywhere, at any time, and on demand could talk to anyone, anywhere else, with ease and clarity. Added to this has always been the economic and social objective of a cost so low as to offer no substantial bar to an essentially untrammeled use of telephony by anyone who has occasion to talk with another at a distance.

For the Bell System as a public service agency, all this is succinctly stated in the frequently quoted objective of the best possible service at the lowest possible cost consistent with financial stability and fair treatment of employees. When, however, one attempts to translate this broad objective into the concrete technical terms needed for its fulfillment, the phraseology is quite different.

For the research man and the engineer, the goal is one compounded of a transmission art so perfect that distance per se is no barrier; that telephone circuits and all they require in auxiliary apparatus for proper operation can be produced so cheaply as to be available in the profligate numbers required for a universal no-delay service; and, finally, that the vast society of Lilliputian currents must live amicably with each other tightly packed together in a world of Brobdingnagian interference.

It is a distant goal even when viewed through the glasses of perfection that picture direct circuits for every desired connection. It is doubly distant when their practical senses tell the scientist and engineer that they must attain part of the solution with indirect switched circuits and, further, that these switches must neither delay the service nor affect its quality appreciably.

The goal of perfection is still ahead, but we have made astonishing progress toward it in the quarter century since the first voice spanned the continent. In very large measure this progress is directly the result of developing fully the latent possibilities of the physical instrumentalities unearthed in the search for an answer to transcontinental telephony. There may seem to be little connection between the quest for an amplifying device to solve a specific transmission problem in 1914 and an engineering study in 1939 to work out a nationwide traffic-routing system, and yet one is the direct lineal descendant of the other.

Visualizing the Telephone Network

In considering the evolution of telephony, we are dealing with a structure that does not lend itself to pictorial representation. But if the reader could be transported rapidly, magic-carpet-wise, out across the continent 3,000 miles or so, thus enabling him to visualize what a complex thing is this creation we are considering, he might acquire at least a superficial conception of its elaborateness and seeming fragility. Only in this way would he fully sense how remarkable it is that this far-flung and delicate structure

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Essential substance of the Thirteenth Steinmetz Memorial Lecture delivered under auspices of the Steinmetz Memorial Foundation at a meeting of the AIEE Schenectady (N. Y.) Section, November 2, 1939.

should be endowed with surprising electrical stability and immunity to meteorological and man-made interference.

Let us imagine at the outset a single pair of wires extending out the window and thence across-country for hundreds or even thousands of miles, and let us bear in mind that these wires by virtue of their length have become possessed of considerable amounts of distributed capacitance, inductance, and leakage—and are, in addition, subject to a variety of induction effects from paralleling communication and power circuits.

Moreover, in many instances this pair of wire is packed tightly together with many similar pairs and enveloped in an impervious lead sheath to form a cable in which a neutral gas, such as nitrogen, is maintained under pressure, and which, should a leak in the sheath develop, operates an alarm circuit to sound a distant SOS. We must also note the presence on many of the pairs of loading coils spaced at regular intervals varying from about $^5/_8$ mile to $1^1/_8$ miles, depending on the type of cable. Each loading coil is a winding of wire on a special magnetic core. Its function is to assist the speech currents, as they travel, to overcome the large attenuating effect of the electrostatic capacitance of the tightly packed wires. These coils, of which as many as 2,000 or 3,000 may be called into play in the handling of a single message, must be electrically identical to a very high degree. Next, there is the repeated and uniform twisting of each pair of wires at its own particular pitch to secure such nicety of balance, both electrostatic and electromagnetic, that not more than a millionth of the power of a telephone circuit will pass over inductively to any neighboring circuit. Then at intervals of 50 miles for certain types of cables, and at shorter intervals—even as low as 5 miles—on certain newly projected types, we would find thermionic amplifiers which restore the message energy after attenuation by resistance and other forms of dissipation. Closely associated with some of these amplifiers are other devices which suppress electric echoes or which automatically counteract the effect of changes in conductor resistance induced by changes in temperature.

The Fundamental Requirement an Amplifier

Many of the features of a long telephone line just enumerated are comparatively recent accomplishments; they project me somewhat ahead of my story. We must return to the year 1914, when a long-distance telephone line consisted of a pair of large copper wires strung in the open and with magnetic loading coils spaced along it at intervals of eight miles. The day of speech current amplifiers had not arrived except for a carbon microphone type which because of distortion was applicable only as a single-stage amplifier on nonloaded lines. Every long circuit operated essentially upon the basis that no energy came out at the receiving end that was not introduced at the sending end—and, needless to say, very little of that. It was also necessary to preserve enough of the energy at the various frequencies represented in speech so that intelligibility was not sacrificed—a requirement that added appreciably to the problem. With the use of eight-gauge hard-drawn copper line wires (weighing 870 pounds to the loop mile) augmented by loading, it was just possible to carry on a conversation between New York, N. Y., and Denver, Colo. How slight the margin of safety was in that line is well illustrated by the fact that it had an equivalent loss of about 35 decibels, so that the power at the receiver amounted to only about 1/4,000 of the power sent out by the transmitter. On this same basis a telephone line spanning the continent would have yielded only 1/400,000 of the power applied to it at the transmitter.

A comparison of these two figures shows at once that there was no hope of solving the problem of transcontinental telephony by some scheme that would apply to the circuit a larger power than the typical telephone transmitter. Any feasible solution must necessarily involve some sort of current rejuvenation at several points intermediate between transmitter and receiver, since the use of heavier copper was economically unsound; in other words, tandem amplification with all its obvious difficulties was the only way out. The search for a successful amplifier or repeater extended over years, and almost simultaneously three promising devices were brought to the point of trial: One, an improvement of that already mentioned, was a mechanical structure that used the amplifying property of the carbon microphone; one a low-pressure arc which possessed a negative resistance characteristic; and, finally, one that employed an electronic current controlled electrostatically by a grid of metal wires placed athwart it. This third arrangement obviously was derived from the audion of Lee deForest, which he was then using to receive radio signals.

To those who were concerned with the problem of the telephone repeater at that time, it was far from evident which of the three alternatives would ultimately win in the struggle for existence. However, the answer was not long in revealing itself. The behavior in practical tests of the electronic vacuum tube designed especially as a telephone amplifier left no doubt that it was at once satisfying in its then performance and full of promise as to additional applications in the future. As we look back upon that situation in the light of our present knowledge, perhaps our wonder is that so recently the ubiquitousness of the vacuum tube should have lain unrevealed.

Laboratory Techniques

We must bear in mind, however, that it employed a high vacuum and that pumps for creating such, even within the physics laboratory, were but lately introduced; moreover, that it also contained a fragile filament—sometimes coated and sometimes metallic—which served as electron emitter and which was subject to little understood vagaries. The making of vacuum tubes, far from being a factory process, called for the skill and personal supervision of the laboratory; and even after this bestowal of care the filament might fail in a few hours or a minute leak might destroy the vacuum and thus end the life of a device upon the making of which many anxious hours had been expended and on whose reliability the integrity of service depended.

I realize that these few words will give but a very imperfect picture of the task confronting those who undertook to adapt deForest's audion to the work of the telephone repeater. Unless one has tried with a molecular pump (so-called) and a liquid air and charcoal combination, and aided by baking and bombardment, to drive a seemingly endless amount of gas out of glass walls and metal plates and grids of a tube, and yet leave the activity of the filament coating unimpaired, he can scarcely realize the hurdle the telephone engineers of nearly 30 years ago had undertaken to clear. And suppose an experimental line were to prove workable, what chance would there be, considering the highly personalized production techniques and the final fragile character of the vacuum tube as then constructed, that the line could ever be more than an unreliable appendage to a network of shorter circuits?

To those as familiar with sturdy vacuum tubes as with incandescent lamp bulbs, it becomes impossible to recount 25 years' progress step by step with the intention of finally revealing the present status in climactic fashion. Instead, my objective will be, by dealing in engineering values, to bring out the interplay of the more significant factors, tracing the line of development and argument that has completely remade the technique and the instrumentalities of long-distance telephony.

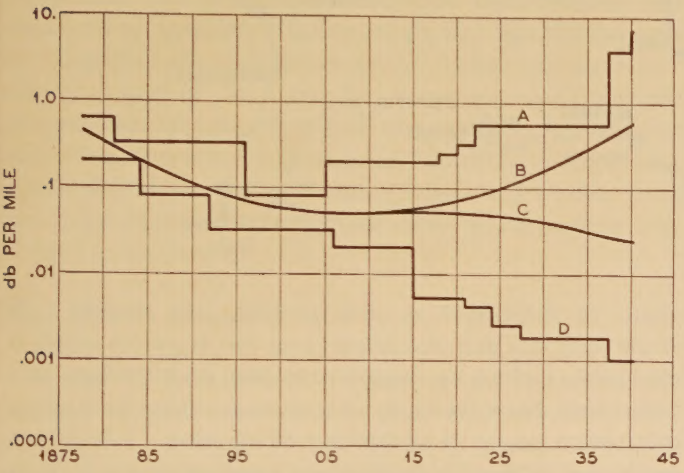

Figure 1. Attenuation loss in long-distance telephone lines

Curve *A* is for circuits having the highest attenuation per mile; the extreme for 1940 represents the coaxial cable now being installed

Curve *B* is the average for all lines, without repeaters

Curve *C* is the over-all average for all lines, including repeaters

Curve *D* is for circuits having the lowest attenuation per mile after repeaters have been taken into account

A Changing Point of View

The advent of the vacuum-tube amplifier radically changed the point of view of the engineer regarding long-distance telephone lines. Over a period of years he switched from a policy of extreme parsimony to one almost of prodigality. Where initially his every thought had been to design lines so as to minimize the possibility of energy loss at every point, he later chose smaller and smaller line wires deliberately because the saving on copper more than compensated for the additional amplification entailed. Figure 1 may be of interest in this connection. Curve *B* shows that during the period from 1880 to 1915 the average loss per mile fell, the reason being that heavier and heavier copper was resorted to. Then, in 1915, with the advent of repeaters, the circuit attenuation began to mount since lighter copper and higher frequencies could be employed. On the other hand, the over-all loss including repeaters (curve *C*) still continues to decline.

Prior to the repeater, the loading coil was of paramount importance as a conserver of the power of the telephone currents. As so frequently happens in engineering design, this economy was not always to be obtained without paying a toll. For instance, in the first transcontinental line loading had to be pushed to such a point that a serious degradation of speech quality resulted. The more heavily loaded a telephone line—that is, the larger the inductance of the loading coils associated with it—the narrower becomes the band of frequencies the line can transmit. It was the discovery of this effect of loading that led a few years later to the invention of the electric wave filter. The discovery was made mathematically by Doctor George A. Campbell, who but recently retired from the Bell Telephone Laboratories' staff (*EE Jan. '36, p. 122; Dec. '37, p. 1518*). He it was who saw the possibility of simulating and generalizing the effect of a long telephone line, by lumped inductances, capacitances, etc., to the end that very compact electric wave-filter circuits could be constructed.

First Experimental Line

Returning to the first experimental transcontinental line of 1914, it included three repeater units, placed at Pittsburgh, Pa., Chicago, Ill., and Denver, Colo., respectively. These, when supplemented by very heavy loading, were just sufficient to make the circuit usable. The quality of speech transmitted left much to be desired, however, for the inductance of the loading coils was such that an effective band of speech frequencies only about 900 cycles wide could traverse the line. This is to be contrasted with a band about 2,500 cycles wide handled by ordinary circuits today, while those employed for interconnecting radiobroadcast stations may transmit a band three times this latter figure; and even this is but a fraction of the band of carrier frequencies that a multichannel carrier system will transmit.

The original transcontinental line with but three repeaters was purely experimental. It proved, however, that the country could be spanned telephonically, and it also established the supremacy of the vacuum-tube amplifier as against the arc and the carbon microphone. Shortly after commercial service started in 1915, six repeaters were substituted for the original three, and these were, of course, spaced about as uniformly as the location of cities and towns would permit. The line itself had a loss of about 60 decibels and the repeaters gave a gain of about 40 decibels. Of course, the day of unattended repeaters and automatic gain control was still undreamed

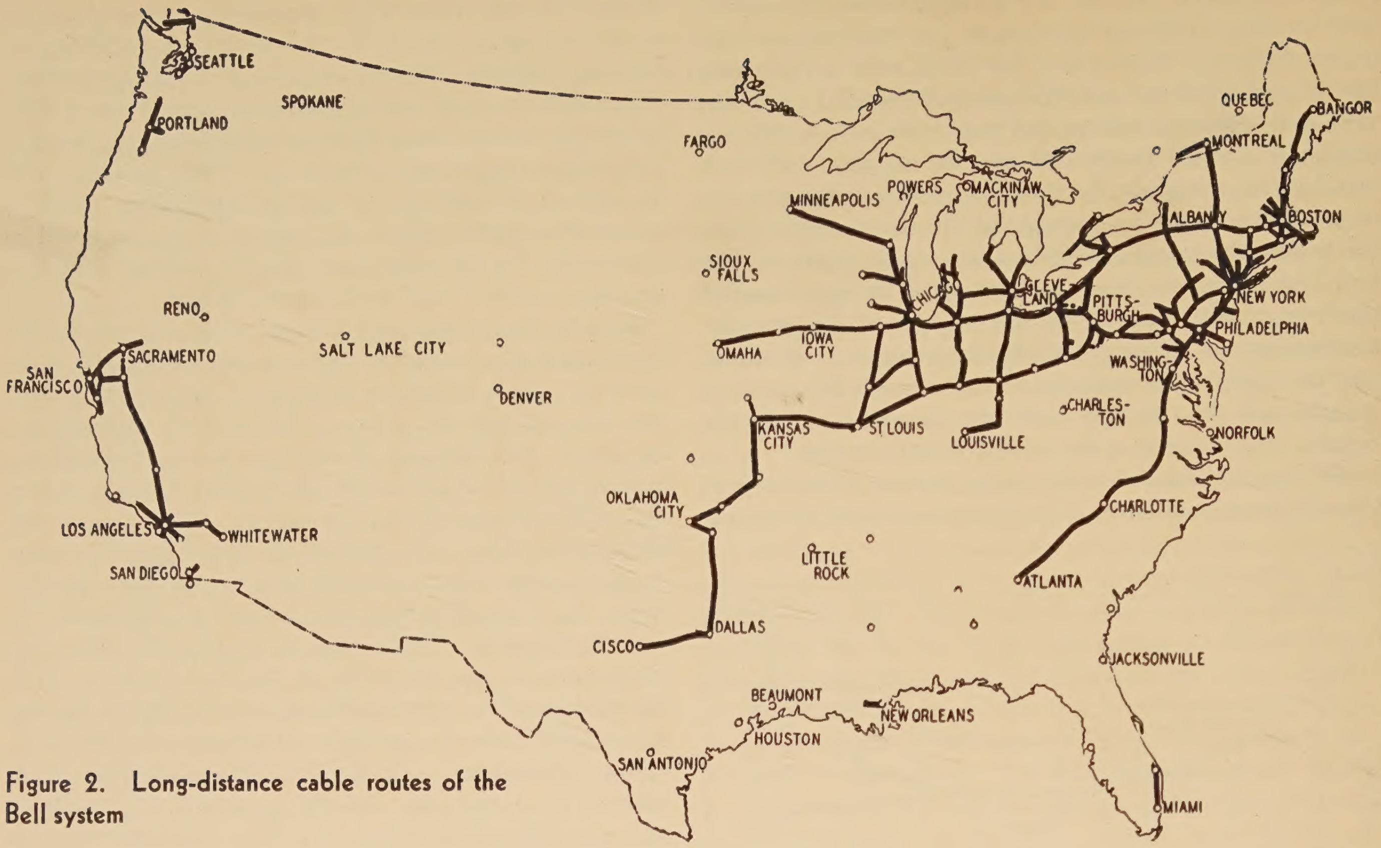

Figure 2. Long-distance cable routes of the Bell system

of. Even with six repeaters it was necessary to retain heavy loading, so that the original line represented about the allowable minimum in commercial speech quality.

The vacuum tube quickly revealed itself to be a fertile subject for research. Over a period of a few years, more efficient and more durable filaments were discovered, and improved assembly methods were devised as well as methods of rapid evacuation. Thus, it became possible, step by step, to be more generous in the use of repeaters in the long-distance telephone plant. The accompanying table traces history from this standpoint. With success accumulating behind us, particularly by way of improved repeaters and enhanced knowledge of how to operate many repeaters in tandem, it was not long before we overhauled the original transcontinental line, removing the loading coils altogether. Thus, the one device which a few years before symbolized long-distance telephony had now begun to slip. Coil removal from the transcontinental line was dictated both by a desire to improve speech quality and to obtain more circuits. The *demand* for service was increasing in response to *improved* service, and removal of the loading introduced the possibility of multiplexing the lines with carrier systems, so where we had originally only three circuits we could now operate nine.

Utility of the Repeater

At the same time, as may be inferred from the table, repeaters were becoming more and more common on circuits of intermediate length. In fact, the importance of the repeater is in considerable part attributable to the changes it has been instrumental in working in the entire toll plant, in short-haul as well as long-haul circuits. As illustrating this and also illustrating the degree to which it has enabled telephone engineers to plan their circuits on a basis other than the early one of conserving the ingoing transmitter energy, I should like to mention a toll project employing cable with small-gauge conductors which dates from about 1920, that is, five years after the initial transcontinental success.

In a cable, because the wires of each pair are close together and therefore have large electrostatic capacitance compared with an open-wire pair, the attenuation is great unless very heavy conductors are employed. Even then the distortion in nonloaded cables is great, and so for many years cable was anathema in toll circuits prior to the repeater. In other words, so long as the initial ingoing energy was all that could be invoked for reproduction of the message at the receiver, cable was generally rejected.

Nevertheless, cable possesses other virtues so obvious that the toll engineer always eyed it with the deepest envy. Circuits in cable are inherently stable because they are protected from atmospheric moisture. They are also less liable to breakage and to inductive disturbances from paralleling circuits, notably power lines. However, the full virtue of a cable is not realized until the density of traffic becomes large enough to require a large group of circuits. A full-sized toll cable, for instance, may contain as many as 300 or

Voice-Frequency Repeaters Installed in Bell System

Year	Total*
1908	16
1910	41
1915	136
1920	1,250
1925	7,500
1930	80,000
1935	102,000
1938	107,000

* As of December 31.

400 separate lines, and as a normal daily message capacity of a single circuit is perhaps 30 to 40, the potential capacity of such a cable is relatively large. It developed, however—and perhaps it was one of those fortunate coincidences—that by the time a cable became feasible from the technical point of view, the demand in the regions of denser population had risen to a height to justify it economically. Omitting reference to an early heavy-wire cable between Boston and Washington, which was operated without repeaters and which was installed because it was deemed important to have unfailing telephone service along this portion of the Atlantic seaboard, the first repeatered cable (and it was therefore one employing relatively small gauges of wire) was placed between New York, N. Y., and Pittsburgh, Pa., with the plan of extending it as need arose to Chicago, Ill., and perhaps to points farther west. The New York-Pittsburgh section was engineered in 1920 and went into service in 1922, seven years after the transcontinental trial had affirmed the value of the repeater. Today, so rapidly has the demand for long-distance telephony grown, that we have not simply a spur of toll cable, but a system which without exaggeration may be referred to as a network. As may be seen from figure 2, it runs from Maine to Georgia and Texas, and as far west as Omaha, Nebr., and Dallas, Tex., and interconnects the important cities of the eastern half of the United States.

Toll-Cable Attenuation

It might be interesting to digress for a moment at this point, so that we can see how far we have progressed over a period of 25 years in the attack upon attenuation. As mentioned before, the original transcontinental line had an attenuation of 60 decibels, of which about 40 decibels was neutralized by six repeaters. Large line wires and loading coils were employed to minimize the part to be played by the amplifying elements in the circuits. How vastly different the situation is today. The attenuation of a cable circuit connecting New York and Pittsburgh is 200 decibels, while for one connecting Boston and Dallas it is 1,100 decibels. To write these results in the form of fractions gives, for the first, 10^{-20}; and the second 10^{-110}. In other words, a telephone message in traveling from Boston to Dallas must receive a 10^{110}-fold amplification in order that it may be compensated against the incursions of attenuation. If this enormous amplification all had to be applied at the sending end of the circuit, there probably would not be enough energy in all the coal reserves of the earth to do the trick. Success lies in doing a little bit at a time, for between Boston and Dallas there are some 45 repeater points (the precise number depending upon the routing) and the average gain of a single repeater is about 23 decibels, or about 200-fold on an energy basis.

Such figures as I have just cited, however, are mere child's play nowadays. There is adequate justification in numerous instances for undertaking the multiplexing of cable circuits by the carrier principle. Not only does such an arrangement effect further economies in copper and lead, but what is perhaps more important, the transmission of the high frequencies of carrier systems involves the removal of all loading coils. This, to be sure, causes the attenuation to mount, but a compensating gain appears in reduced time of transmission. Loaded cable circuits possess a relatively slow speed of propagation—perhaps 10,000 to 20,000 miles per second—with the result that for the longer circuits, the echo which returns to the speaker from the far end of the cable lags sufficiently in time to be extremely disturbing. To avoid the echo difficulty, the longer loaded cable circuits are equipped with so-called echo suppressors which operate to permit propagation in only one direction at a time, and are controlled, of course, by the person who first starts talking after any pause. But with nonloaded cable circuits, including all equipment, the speed of propagation jumps to around 100,000 miles per second—more than half the speed of light in free space—with the result that except on extremely long circuits the echo is not separable by the ear from the inducing sound.

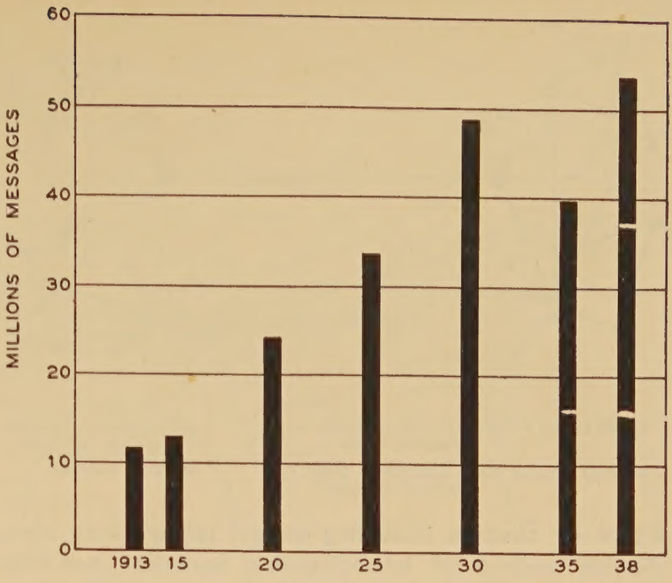

Figure 3. Growth of long-distance telephone traffic

But what of the attenuation? It seemed high enough on *loaded* cables. It naturally jumps manyfold, but not more than the capacity of repeaters to counteract. Circuits are in daily use in which the attenuation is as much as 2,400 decibels, and experimental lines have been formed and operated by the looping back and forth of several cable pairs to build up the equivalent of an 8,000-mile straightaway whose total attenuation was about 12,000 decibels. Such a circuit needs a total amplification on an energy basis, amounting to $10^{1,200}$, a ratio so enormous that it quite transcends ratios such as the size of the total universe to the size of the smallest known particle of matter.

Naturally, the problem of balancing this huge amplification against the correspondingly huge loss to the required precision, one or two decibels, is difficult. Fortunately, a new form of amplifier employing the principle of negative feedback was invented by H. S. Black of the Bell Telephone Laboratories, which has enabled us to solve the problem. By using Black's negative feedback we are in possession of amplifiers giving 50 to 60 decibels gain with a

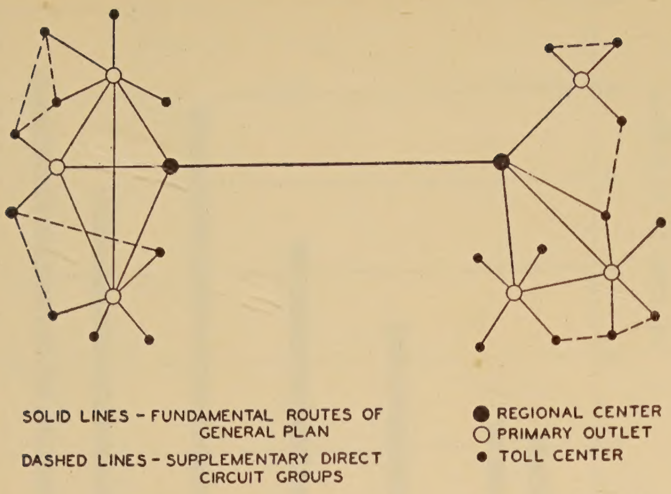
SOLID LINES – FUNDAMENTAL ROUTES OF GENERAL PLAN
DASHED LINES – SUPPLEMENTARY DIRECT CIRCUIT GROUPS
● REGIONAL CENTER
○ PRIMARY OUTLET
• TOLL CENTER

Figure 4. Diagram illustrating general toll-switching plan, showing method of interconnecting important switching offices throughout Bell system

variation of not more than 0.01 decibel with normal battery and tube variations. I might also say that were it not for such a repeater, the coaxial type of cable, which again possesses attenuation of the order we are now considering, would be quite impracticable. Time will permit me to do no more than mention in passing the fact that those large gains must be controlled automatically, particularly in response to temperature changes. Cable circuits, by their nature, show only minor variations in capacitance, inductance, and leakage, but the resistance of their conductors can change by large amounts from winter to summer, and even from hour to hour. These changes are more rapid in overhead cables than in those placed underground. However, automatic regulators, which take their cue from so-called pilot wires running through the cable along with the speech pairs, are necessary in both. Thus, the annual variation of attenuation in a cable circuit may be as much as 100 decibels, or more than the entire attenuation of the first transcontinental line. In fact, the variation experienced on some of the long carrier channels is as great as 250 decibels.

Awakening of Public Demand

With the introduction of toll cable together with carrier systems for both open-wire and cable circuits, there was a steady and supporting growth in the demand for long-distance telephone service. Figure 3 shows how rapidly toll traffic has grown. Over the period of the last 25 years, the American public truly seems to have become long-distance-minded. This illustrates what, to my mind, is one of the important principles of engineering that we see exemplified in many lines of industry, namely, that the volume of demand is governed by a complex assemblage of such factors as cost, convenience, and ready availability. Unquestionably the most important factors stimulating growth in demand for long-distance telephone service have been increased convenience, reliability, speed of service, and quality of speech reproduction.

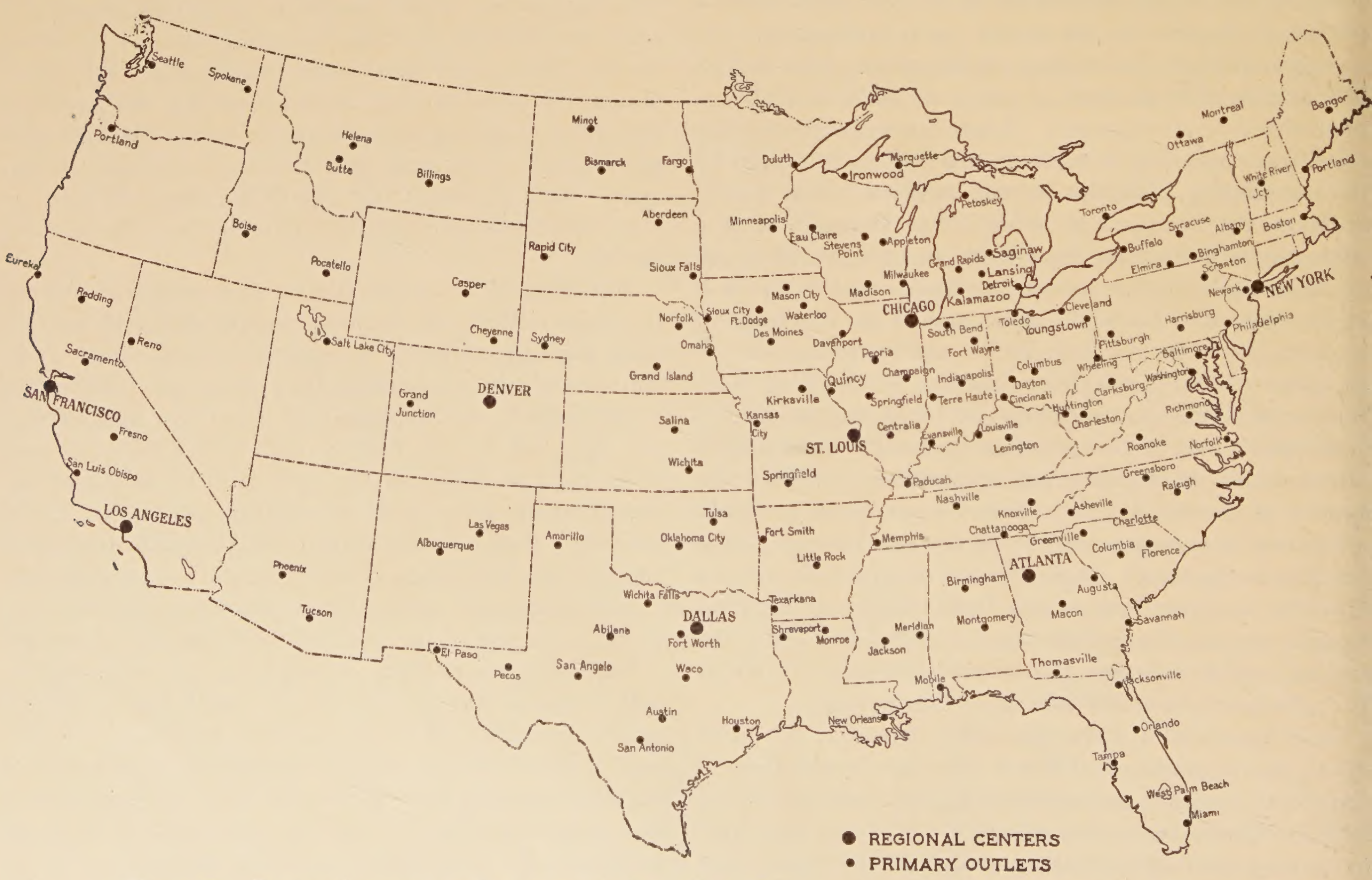

Figure 5. Regional centers and primary outlets of the Bell system in the United States and Canada

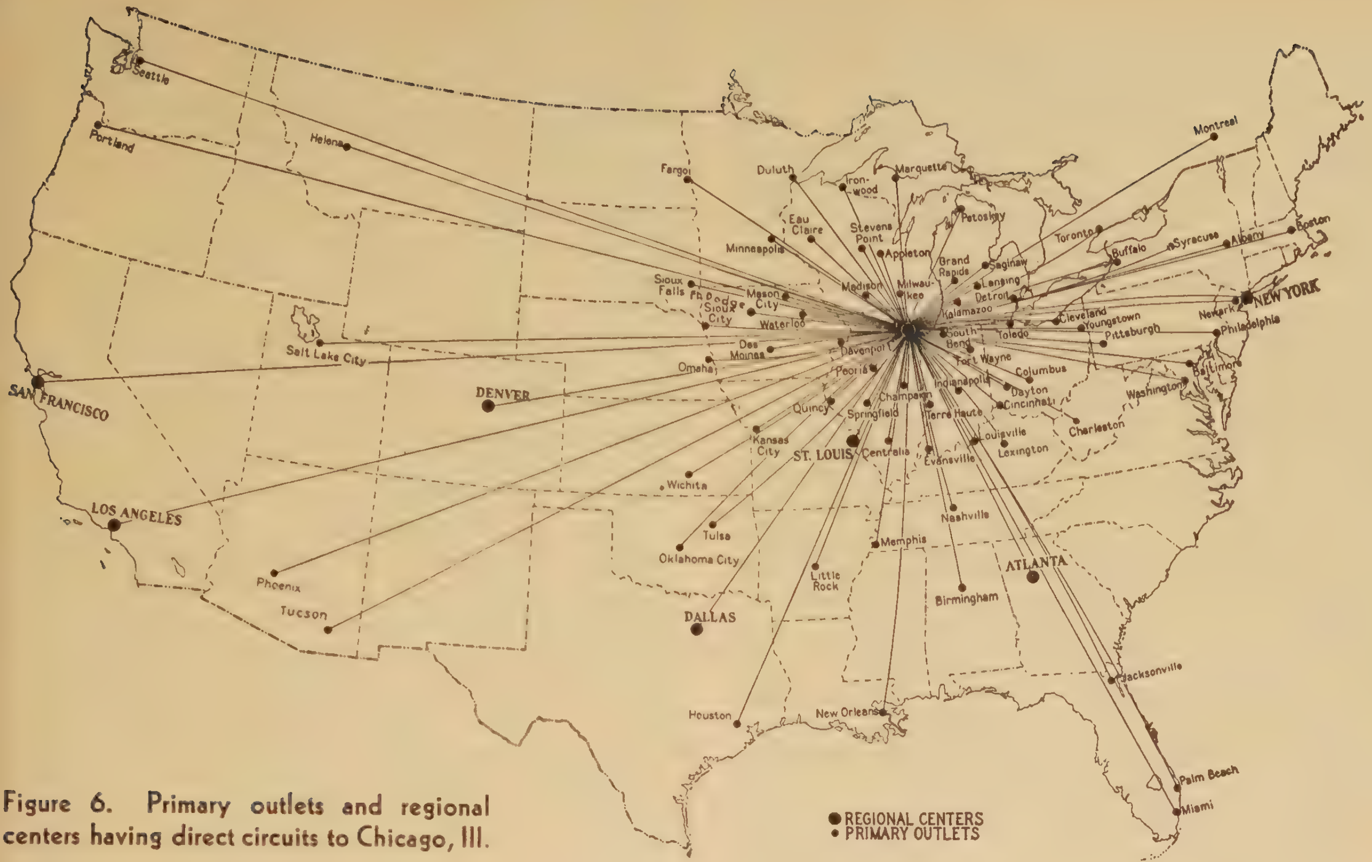

Figure 6. Primary outlets and regional centers having direct circuits to Chicago, Ill.

Our chief objective, of course, in providing more circuits of adequate transmission efficiency has been to cut to a minimum the delay the calling subscriber experiences before reaching his called party, thus increasing the value of the service and incidentally inducing him to use more of it, a result which in turn makes additional circuits necessary. This to-and-fro process has been influenced by periodic reductions in rates as improved facilities and a larger density of traffic have permitted. Nor should I fail to mention that one of the most important factors in this "chain reaction" has involved the development of superior operating techniques and more direct-circuit routings which have been of assistance in enabling the operators to reach distant points quickly.

These considerations lead to a discussion of what we call a general toll-switching plan. It is quite apparent that when the art has reached a point where seconds count in completing calls, very careful study indeed must be given to the question of where unnecessary seconds can be clipped from our operating times. Such a study must be nationwide, for it must give attention to the calls that pass between far corners of the country as well as to those that flow over the heavy-trade routes. At the same time, it is equally obvious that the solution does not lie in direct circuits from each exchange to every other exchange. Such an arrangement would be too profligate and unwieldy to be commercial. However, due weight must be given to the fact that the toll business has shown a more rapid growth over the longer distances than over the shorter ones.

All measures of the quality of service—speed, accuracy, and transmission—show that the difficulty of giving satisfactory service increases rapidly with the number of intermediate switches. The general toll-switching plan, therefore, involves the layout of toll circuits in such manner as to limit as much as practicable the number of switches required to connect any two telephones, and also the establishment of standards of design and construction giving satisfactory transmission over any route thus established.

Toll-Switching Plan

The general features of the plan may be understood by reference to figure 4, which shows the application to a limited operating area such, for example, as a region of the United States. Within the area are selected a small number of important switching points designated as "primary outlets." Each toll center is connected directly to at least one of these outlets and all primary outlets within the area are directly interconnected. This makes possible the interconnection of any two toll centers within the area with a maximum of two switches and within the part of the area served by one primary outlet, with a maximum of one intermediate switch.

The primary outlets have been selected after a careful study of the switching and operating conditions and the probable development of toll traffic within the various areas with a view to obtaining the minimum number of primary outlets capable of handling the traffic economically. The routings provided by the plan are supplemented by direct circuits, or by other routings where the amount of business justifies such additional circuits as indicated by the dashed lines in figure 4. In general, these supplementary routes are required to be at least as satisfactory, both as regards number of switches and transmission, as the routes provided by the fundamental switching plan. However, when the supplementary routes are used only as alternates to a primary routing they may be somewhat less satisfactory in these respects.

The nationwide array of primary outlets is shown in figure 5. We have found it practicable to take care of switching for the 2,500 toll centers of the United States and eastern Canada by the establishment of approximately 150 of these as primary outlets.

To facilitate the handling of longer-distance traffic, eight of the largest cities have been designated as regional centers: New York, N. Y., Chicago, Ill., St. Louis, Mo., Atlanta, Ga., Dallas, Tex., Denver, Colo., and San Francisco and Los Angeles, Calif. Each primary outlet is connected with at least one regional center and with as many more as practicable. With few exceptions, each regional center is directly connected to every other regional center in the country. However, there are many more direct routes than this statement would imply. By this means, any one of the primary outlets, which are the 150 most important switching centers in the country, can be connected to any other primary outlet in the country with a maximum of two switches, and within the area served by a regional center with a maximum of one intermediate switch. As an illustration of the concentration of switching that results, New York serves as regional center for the entire northeastern United States and eastern Canada.

Figure 6 shows the direct circuits radiating from Chicago. As may be noted, several important cities in the Mountain States other than Denver have direct lines to Chicago. Furthermore, some cities in the South can be reached without a switch at Atlanta.

One possible ultimate development would be the increasing connection of primary outlets to a single regional center so that ultimately only one regional center would be necessary. If this were to take place, the regional center would undoubtedly be Chicago. As shown by figure 6, over one-half of the primary outlets already have direct connection with that center.

Future growth will doubtless lead to an increase in the number of toll centers connected directly to a regional center. By this process there would be a continued growth in the number of toll centers that can be interconnected with a maximum of two intermediate switches.

Looking to the future, an increasing amount of the outgoing traffic will be handled by operators in the local central offices, reaching the toll line over toll tandem trunks. It is evident, however, that the ultimate solution of the problem will involve the use of machine methods for the selection of the toll line by the operators, as is now done in certain segregated toll tandem systems.

The entire trend of recent years is thus to decrease the differences between the handling of exchange messages and of toll messages. At present more than 90 per cent of the toll messages are completed while the subscriber remains at the telephone with speeds of completion only slightly slower than those of exchange messages. Transmission standards, while naturally somewhat better for the shorter distances involved in exchange messages, are, nevertheless, rapidly becoming very comparable. The present view of trends for the future is for continuation of this process, perhaps even to the use of similar types of machine equipment at central offices for switching the various classes of messages.

Additional Transcontinental Lines

In order to justify the reference to transcontinental telephony in the title of this discourse, I must return to it from time to time. I do so again at this point to mention that the original line with 3 circuits has now become four routes with 178 circuits. It may have been surmised from the discussion of the toll-switching plan that the number of coast-to-coast circuits must have mounted steadily and that they probably were directed over divers routes. This, precisely, is the situation. Following the historical sequence, second in order of time was a line running west from Dallas, Tex. (1923) and terminating in Los Angeles, Calif. This carries 51 circuits, 27 voice frequency and 24 carrier. Next there followed the so-called northern transcontinental line which runs west from Minneapolis, Minn., and terminates at Seattle, Wash., and which has 6 voice-frequency and 9 carrier-frequency circuits. Finally, there was completed about three years ago a fourth route which runs west through Oklahoma City, Okla., and, passing through Albuquerque, N. M., terminates in Los Angeles. It carries 4 voice-frequency and 52 carrier-frequency circuits. As may be seen, therefore, carrier systems predominate today in supplying facilities for the longest distances. I might add that whereas earlier carrier systems developed some 20 years ago were designed to provide 3 and 4 carrier circuits per pair of wires, the latest systems to be introduced, for both open wire and cable, are 12-channel affairs, while the coaxial cable now undergoing installation for commercial service will provide hundreds of telephone circuits on a single pair of conductors. Of course, these systems are and will be increasingly used on routes other than transcontinental. At present we have a total of about 600,000 miles of carrier circuits, and so far as the telephone user is concerned, and even so far as our own traffic people are concerned, there is no distinguishable difference between a voice-frequency and a carrier circuit.

Earlier I mentioned the electric wave filter invented by Campbell. It is, of course, in connection with carrier systems that the filter finds its most important application in telephony. It provides a most elegant scheme for separating at the point of reception the various messages that a carrier system handles simultaneously. As stated before, it was an outgrowth of the mathematically deduced characteristics of the loaded line. Thus, we stumble upon another interesting relationship. What we put out at one door comes around through another, for while we have dispensed quite generally with loading coils on long lines in order to adapt them to carrier operation, carrier itself would not be feasible were it not for the wave filter which grew out of the loaded line.

Overseas Radio Extensions

From carrier systems it is natural to digress for a moment to other high-frequency facilities. Chief among these are the radiotelephone channels, some overseas and some for ship-to-shore and harbor operation. The topic of radiotelephony is pertinent to the present discussion for quite another reason, however. It was less than a year after the first transcontinental line was opened in 1915 that we succeeded in transmitting speech by radio across the Atlantic Ocean. Words emanating from the Arlington antenna near Washington, D. C., were received at the Eiffel Tower in Paris, use of both structures having been granted for the purposes of the experiment. The vacuum tube, which brought success to the transcontinental program, began early to show its versatility. However, transatlantic equipment of 1915 was crude in the extreme compared with what proved necessary to offer a commercial overseas service. Although a one-way demonstration from New York to London was given in 1923, it was not until 1927 that the British Post Office, which operates the telephone system in Great Britain, countered with a transmitter to send from east to west. Since that time, overseas channels have bobbed up with surprising rapidity all around the earth so that today some 97 per cent of all the telephones in the world can be connected, one to another. From the United States we can telephone to 74 other nations—or can when peace-time conditions prevail.

I must now undertake to conclude this discussion of what grew out of one particular kernel, if you will allow me to refer to a circuit some 3,000 miles in length as a kernel. Perhaps it might better be compared with one of those long chain molecules which the chemists are employing these days with surprising results. Time forbids more than a mere mention of numerous other essential devices which are playing their part in this broad subject of present-day telephone transmission. Such things as phase correctors, automatic gain control of repeaters, volume compressors and expanders, and echo suppressors, ought really to receive more comment, to say nothing of various refinements in operating techniques which have been of great importance. However, I trust that I have succeeded in giving at least a glimpse of how some of the chapters of this technological romance have unfolded.

Thirty years ago the problems of long-distance telephony, and particularly the problems of transcontinental telephony, were very concrete transmission problems. Because the greater obviously included all the lesser, it was taken for granted that a satisfactory solution of transcontinental telephony would have far reaching effect on all long-distance telephony. For the most part we thought of the effect in terms of transmission rather than such things as speed of service or toll-switching plans.

It would be easy to claim too much for the descendants of the physical things that were first utilized commercially in the transcontinental circuits of 1914–15. At the same time, it is largely because of these descendants developed to do a multitude of things that we have present-day national and international telephone service; that the distant party is obtained while the calling party is still at the telephone; that we have a toll-switching plan and can contemplate a better one; and that we can talk about circuits which girdle the globe or operating methods which tend to wipe out existing differences between local and long-distance service.

None of us who were in the game from the start, 30 years ago, were bold enough to envisage what is commonplace today. But each success inspired new effort both in laboratory and field, and by a process of probing into Nature, inductively in the laboratory and deductively by means of mathematics, and with constant study of operating problems, we have, I believe, made creditable progress. I want to emphasize the fact that close co-operation was necessary every foot of the way. In bringing the fruits of science to the service of a vast public in a manner such as the telephone accomplishes, there has been no room for the dictatorial method, except of course as Nature does the dictating. We must try at all times to plead our case intelligently before Nature, and sympathetically before the public. As a matter of fact, the public and its reactions are as much a part of Nature as the electrons that carry our messages, and transgression of its laws of reaction would have been about as inimical to success as would a failure to understand the laws of electromagnetism.

In its journey during the last quarter of a century, telephony has crossed several thresholds, but, even so, the journey may be in its early stages. From the vantage point of the laboratory we see many promises of progress ahead and others quite unforeseen are certain to turn up. I feel, however, that there is something about this casual notion that, like the brook, science and its applications run on forever, which we should not accept too uncritically.

Illumination Notes

Midget Photoflash Lamp. Ten years ago the photoflash lamp appeared, freeing night photography from the nuisance of smoke and the danger of burns that accompanied the use of magnesium flashlight powder. The lamps were the size of ordinary lamp bulbs, so that one filled a coat pocket and a dozen made a fairly large package. Now the "mighty midget" photoflash lamp has been brought out by the Mazda lamp manufacturers. It is smaller than a golf ball, so that a dozen may be carried in one pocket with ease, but it gives a peak flash of nearly a million lumens. It is made with a bayonet base, so it requires an adapter for use in standard sockets.

Contributed for the AIEE committee on production and application of light by L. A. Hawkins (A'03, M'13) executive engineer, research laboratory, General Electric Company, Schenectady, N. Y.

Progress in Power Generation—1933–39

This report of the AIEE committee on power generation* reviews practices and developments in this field since 1933, when the last progress report of the committee was published. It divides itself naturally into three main parts discussing steam, electric, and hydroelectric plant practice. A comprehensive bibliography is appended.

DURING the past six years the most important advances in power generation have been made in the use of 3,600-rpm high-temperature high-pressure steam-turbine hydrogen-cooled generators of large size. Boiler design and construction has been changed to insure sufficient circulation, and welding has taken an increasingly important part in almost every part of the plant equipment, both mechanical and electrical. The period has marked the installation of many superposed units whereby the capacity of existing plants has been increased and the thermal efficiency materially improved. Because these stations are largely located near load centers from which distribution districts are served, there has been much rebuilding and extension of switching facilities of improved design and layout. These changes have greatly lessened the possibility of service interruptions from fire or other causes. Hydraulic power projects have been largely in the hands of Federal agencies. The output of existing hydroelectric plants in many parts of the country has been severely reduced owing to lack of rainfall during the past year.

With the European war there arises the prospect of extra demands on the electric-power systems for manufacturing purposes. For present requirements ample generating capacity is available with a sufficient margin to meet a considerable increase in load. To maintain this margin for growth much new capacity is under construction. In addition, since the beginning of the war about 400,000 kw of steam turbine-generator capacity has been ordered. It is interesting to note that this further expansion is being carried out along the same lines as would normally be followed. It is simply a quickening of the pace of construction, all consistent with earlier prepared plans for plant extension.

Equally careful to the steps being taken to insure an adequate power supply must be the attention given to the physical safety of the plants in operation and under construction. This means special guarding and other precautionary measures.

Steam-Plant Practice

Since 1933, and as predicted then, practically no new large generating stations have been built and very few small ones. Activity has been confined to rehabilitation, principally in the form of superposition of existing capacity. There have also been a number of condensing additions to existing stations.

Development of metals has resulted in an increase of operating steam temperatures from a maximum of 850 degrees Fahrenheit then to 950 degrees. This increase has made possible the superposition of nominal 1,200-pound units on existing 200-pound capacity without the complication of reheat, and consequently this type of installation has been more attractive than heretofore. Also, curtailed economic activity and limited load growth made the relatively small capacities obtainable by this method more in line with requirements. As a result 1,200-pound pressure has become quite common. There has been little tendency to go further in pressure as with present steam temperature limitations reheat would be required. One utility installation, however, is proceeding with a 2,500-pound plant; also, an industrial installation is in operation at this pressure. There has been no commercial installation of any appreciable size for higher pressure than 2,500 pounds, as this is now considered the limit for natural boiler circulation, and forced circulation is as yet untried in the United States for large units.

BOILERS

Boiler sizes have not increased since the last report of this committee, remaining at a maximum of about 1,000,000 pounds per hour. Recent large installations have indicated that the sectional-header boiler is not as desirable for high pressure as other types because of improper distribution of water circulation between individual tubes in the vertical headers. Practically all new high-pressure boilers now under construction are of a type in which the boiler surface proper is either eliminated entirely or disposed nearly vertically with individual tubes entering the steam drum. Welded steel drums are almost universal. All high-temperature installations employ superheat control, consisting of some form of gas by-passing part or all of the superheater surface. Higher pressures have increased the problem of obtaining pure steam. Recent developments indicate that washing is unnecessary, providing either a suitable scrubber or baffling is installed and precautions are taken to hold proper boiler water level in the steam drum. One very satisfactory method of accomplishing this, which has been developed recently, is by means of cyclone separators installed on the outlet of the circulating tubes entering the steam drum.

The trend toward pulverized coal for large boiler units has persisted. Direct-fired systems have been improved to a point where it is difficult to justify the additional expense of a storage system. This has stopped development of large pulverizer units, about 25 tons per hour being the maximum required. Combustion rates in furnaces remain about the same. Slag-bottom furnaces have been on the increase, and on recent units continuous slag tap has displaced the intermittent type. There has been a tendency toward bare water-cooled walls, eliminating blocks and studs.

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* **Personnel of 1938–39 AIEE Committee on Power Generation:** E. C. M. Stahl, *chairman;* H. C. Albrecht, F. A. Annett, G. M. Armbrust, W. L. Cisler, C. A. Corney, H. M. Cushing, J. H. Foote, R. L. Frisby, W. D. Hardaway, N. B. Hinson, J. W. Lingary, S. J. Lisberger, C. E. Magnusson, A. C. Monteith, E. F. Pearson, G. G. Post, C. R. Reid, A. E. Silver, Philip Sporn, Robert Treat, Sidney Withington, and E. D. Wood.

For all numbered references see list at end of report.

Zoned air control for stokers has not advanced as expected. Principal development on underfeed stokers has been an improved tuyère which restricts air flow through the fuel bed at points of low resistance. Present experiments, which look promising, are high-velocity overfire air and auxiliary oil burners over the fuel bed.

TURBINE GENERATORS

There have been no further installations of very large turbine-generator units, the largest now under construction being a 100,000-kw cross-compound 3,600-rpm unit for the Burlington (N. J.) generating station of the Public Service Electric and Gas Company. Where high pressure and high temperature have been employed, there has been a preference for 3,600-rpm turbines because of smaller parts and less tendency for distortion. First-stage blading for the larger machines at this speed has presented a problem in design which has not been entirely solved. Apparently it is a matter of providing sufficient mechanical strength in the restricted space available, along with disposition of parts in a manner that will avoid resonant vibration.

Large-capacity generators for 3,600 rpm made necessary considerable advance in design. The largest generator in operation at this speed in 1933 had a capacity of 18,000 kw, whereas there are now in service a 60,000-kw and several 50,000-kw machines. Increase in capacity has been made possible by the use of high-tensile-strength steels for the fields, hydrogen cooling, and improvements in detail design. Operation of these larger machines has been in the main satisfactory, although there has been some trouble with double-frequency vibration.

There has been very little development of condensers, probably because of the relatively few condensing units installed.

Welding of piping has been carried out to a greater degree than before, and it is now common practice to weld valves into the line. Welded bonnets for high-temperature valves seem to be in the offing.

LJUNGSTROM TURBOGENERATORS

Considerable interest has been aroused in engineering circles by the installation in the Southwick Power Station, Brighton, England, of two 37,500-kw Ljungstrom turbogenerators (see figure 2). These are the largest of their kind in England, although sets developing 50,000 kw are in service in the Vastreas station, Sweden. It is claimed that these latter turbines have shown conclusively that the difficulties once associated with their construction have been completely overcome. It is also confidently predicted that these double-rotation turbines in a single cylinder can be built up to a capacity of 100,000 kw. One of the major advantages claimed for this design is that the turbine may be started without preliminary warming up. Test data on the Brighton machine operating at a pressure of 650 pounds per square inch and a temperature of 850 degrees Fahrenheit with 29-inch vacuum indicate a heat rate of 9,759 Btu per kilowatt-hour.[91] With the present development of this type of turbine they are now adaptable to feed-heating cycles.

GAS TURBINES

Cognizance must be taken of the more recent developments in gas turbines. One of the accelerating factors in this development is the fact that they are being used to provide bombproof stand-by plants, particularly in the fortified areas of Europe. A notable installation is in the city of Neuchatel, Switzerland. These turbines require no cooling water and no auxiliaries when in operation. Over-all thermal efficiencies have attained 23 per cent with well over 20 per cent for the normal operating range.

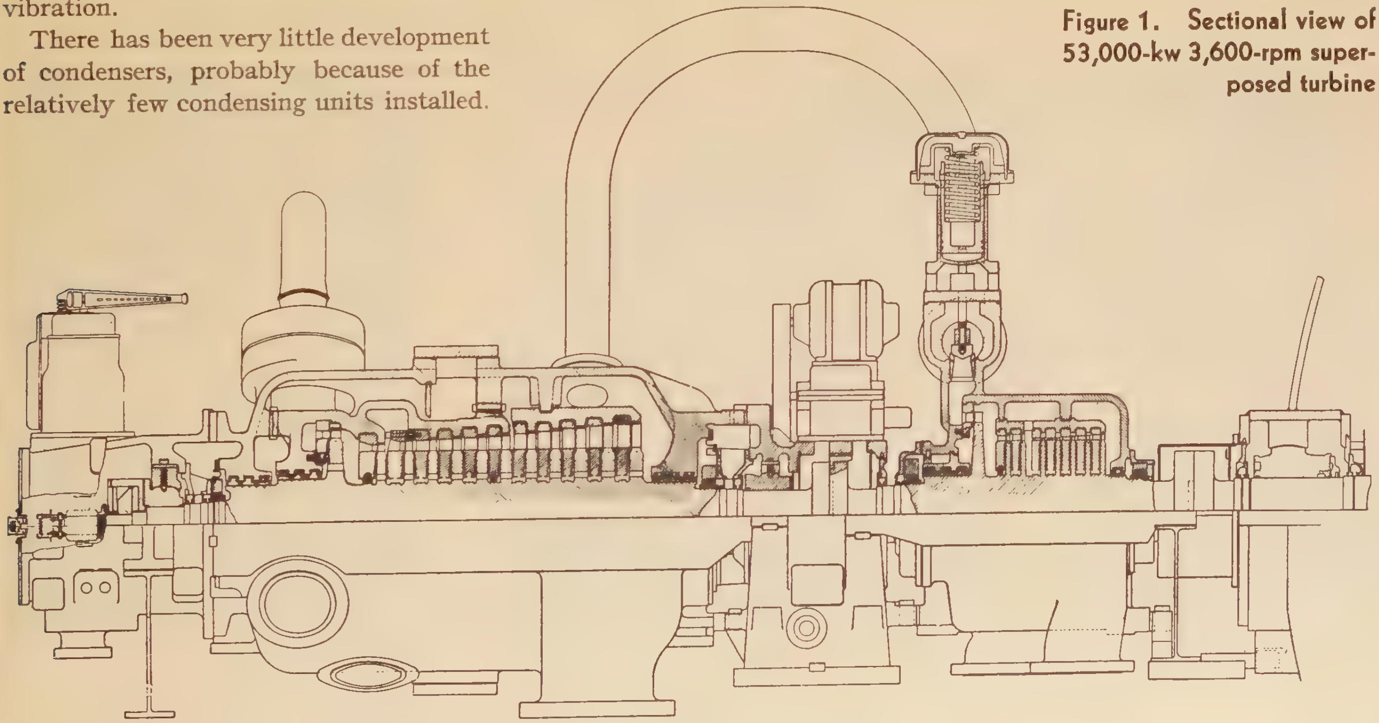

Figure 1. Sectional view of 53,000-kw 3,600-rpm superposed turbine

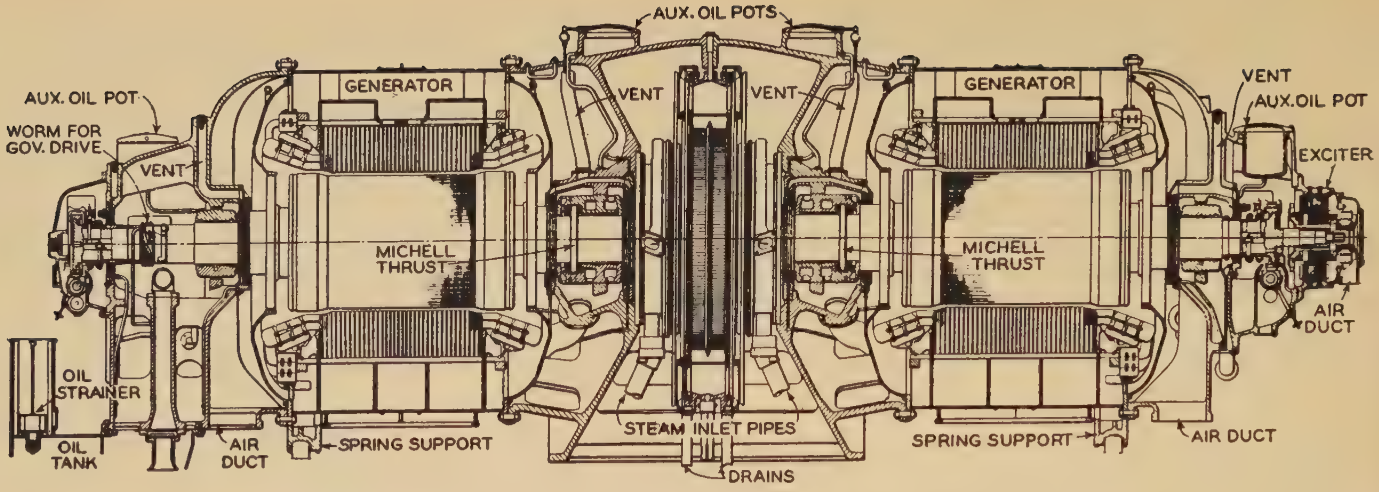

Figure 2. Sectional elevation of Ljungstrom turbine and generators

So far, gas turbines have attained capacities of 4,000 kw.[93]

Mercury Cycle

There have been no additional mercury boiler installations for power generation, although the Sun Oil Company has installed another boiler used in oil distillation process. Considerable trouble developed with the Kearny, N. J., and Schenectady, N. Y., boilers described in the 1933 report of this committee. The Kearny boiler is now being completely replaced. The design of the new boiler is similar to water-boiler design in that there is only one drum. "Porcupine" tubes with internal cores and close clearances have been eliminated. The convection surface is new in principle in that instead of being completely filled with a liquid it carries a mixture of liquid and vapor, resulting in a marked reduction in the amount of mercury required per unit of heating surface. As a result of the elimination of tube cores, however, the total amount of mercury in the boiler is somewhat increased. In the redesign the water-wall furnace has been eliminated, resulting in a marked improvement in over-all efficiency. New materials now available and more suitable for the operating conditions involved are being utilized in the various parts of the heating surface. Operating practice, and particularly chemical treatment of mercury in the boiler, has advanced considerably. The mercury turbine generators have been very satisfactory, and the only recent change in design involves improvement of the turbine glands to reduce air leakage to a minimum.

Electrical-Plant Practice

Generating-Station Switching

Since 1933 few new steam generating stations have been built requiring low-voltage power distribution, with the accompanying bus-layout problems. Large new stations have been mainly of the hydroelectric type, far removed

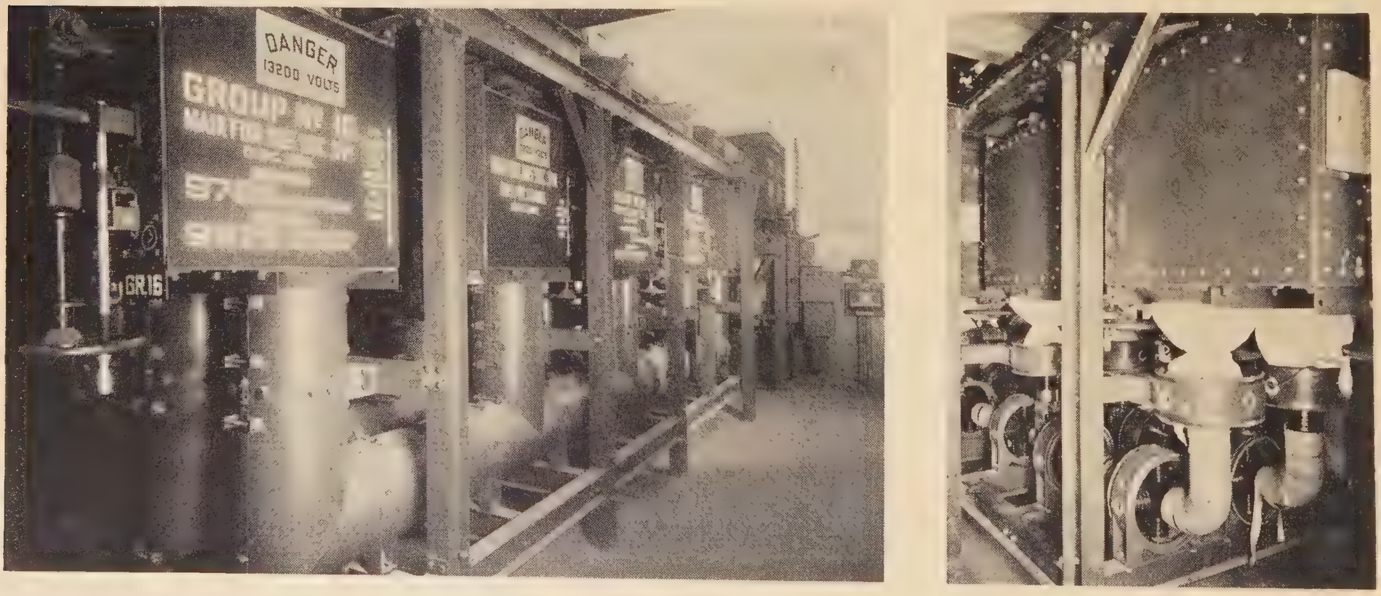

Figure 3. Metal-enclosed feeder bus equipment; the method of supporting and insulating the bus is shown in the construction view at the right

from local load, with generators connected directly to transformer banks or through a minimum of low-voltage switching equipment with outdoor high-voltage switch yards for the connection to the transmission lines, such as the Boulder Dam development.[109]

The generator-voltage switching facilities of several stations have been reconstructed and modernized due in some instances to the addition of generating capacity or extensive interconnecting of systems, and in others to interruptions caused by fires in the older types of switch houses.

One of the first large stations to be modernized was the Connors Creek station of the Detroit (Mich.) Edison Company.[98] In this instance a new switch house, separated from the existing station building was erected to house the modern bus and apparatus.

In the last few years this topic has become of such interest that at the AIEE winter convention in January 1939 the committee on power generation held a session on the rehabilitation of the various stations of the Consolidated Edison Company of New York,[117] the Essex generating station of Public Service Electric and Gas Company of New Jersey[119] and the L Street station of the Boston Edison Company,[116] together with a paper on the general topic.[118] The papers presented at this meeting describe in detail the problems that were present at the various locations, the aim of reconstruction programs, and the methods used by the various designers to obtain the results desired. The authors in agreeing on certain principles show clearly the present trend of switch house construction:

1. Complete relay protection.
2. Improved arrangement of equipment.
3. Limitation of capacity connected to one bus section, so that a fault will not remove too great a proportion of the station capacity.
4. Better physical segregation of bus sections and oil circuit breakers, by means of smoke and fire barriers, coupled with forced ventilation.
5. Reduction of oil content of breakers.
6. Use of improved fire-fighting equipment.
7. Improvement as to control, segregation, and grounding.

As the length and extent of several recent interruptions were in part due to smoke and soot deposits on insulators and busses of portions of the station not directly involved in the fault, great pains have been taken in these rebuilding programs to segregate indoor sections physically. Barriers, without direct doors or other openings between sections, are desirable if the conditions permit. Access to sections is obtained from corridors or rooms free of electrical apparatus, which also may provide expansion space for the dissipation of pressures generated by explosions. With large-capacity ventilating systems to clear the faulted section of fumes, and with adequate fire-fighting equipment present, these modernized switch houses have a strong second line of defense if, in spite of improved protective schemes, an explosion or fire occurs. Recent tests demonstrating the capabilities of fire-fighting equipment and aiding in the training of operating forces have permitted more assurance in their effectiveness. Equipment of both the carbon-dioxide type and of the fine-water-spray or mist type, in both portable and permanently piped systems, has been used.

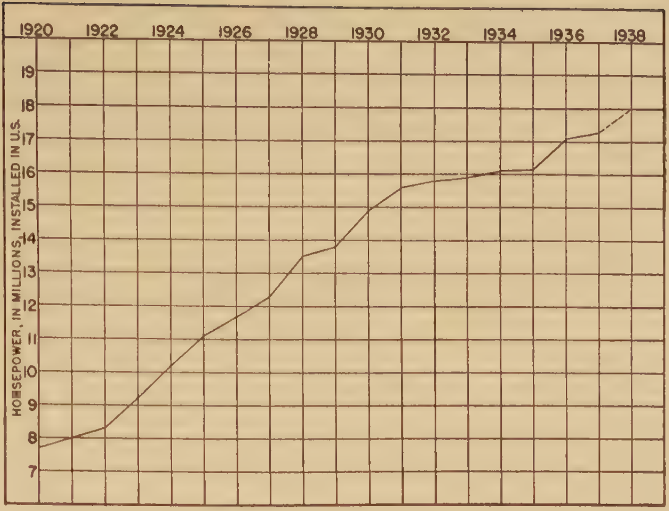

Figure 4. Growth of water-wheel installations in all classes of hydraulic plants in the United States

One of the most interesting recent developments is the nonmagnetic-steel-tube-enclosed gastight bus of the Consolidated Edison Company of New York,[117] which allows phase segregation and high carrying capacity in limited space. A number of installations of the more conventional metal-enclosed bus structures with metal breaker cubicles have been made, and in many such instances fault bus protection has been adopted, although differential protection is in use in the majority of cases.

ELECTRICAL EQUIPMENT

There has been a marked improvement in apparatus and equipment since the 1933 report. Extensive tests on oil circuit breakers with the modern arc-extinguishing devices have produced a breaker both electrically and mechanically more reliable than was heretofore available.

Opening times of eight cycles are now standard, and breaker speeds of five and three cycles may be obtained when necessary.

Many old oil circuit breakers have been equipped with the new arc-extinguishing devices and higher-speed mechanisms to gain in interrupting capacity and reduce the time to the present AIEE standard.

The tendency to reduce the oil content of breakers has caused a general interest and demand for oilless breakers, which has resulted in an increased use of available designs and new developments by the manufacturers. Breakers of the air De-ion type are in service with up to 750,000-kva interrupting capacity; breakers of the hydro-blast type are in service rated at 500,000-kva interrupting capacity with orders placed for capacities up to 1,500,000 kva; and breakers using compressed air as an arc-extinguishing medium are on order with interrupting capacity of 500,000 kva and are designed with ratings up to 1,500,000 kva.

Disconnecting switches have been developed for large capacities, mainly of the high-pressure type, using button or line contacts, or positive clamping action, all with silvered contacts; tests have shown them superior to those previously available for continued service at full loadings. High-capacity busses show a trend away from the flat-bar configuration toward the tubular, rectangular, or double-channel iron forms. Busses both with and without insulation in addition to the porcelain supports are used.

Manufacturers' research in test methods, increased laboratory facilities, and the accompanying design improvements as regards impulse strength, together with the work of the transformer subcommittee of the AIEE committee on electrical machinery, have made data available in the past few years so that the station designer may grade the insulation for surges in addition to normal frequencies, although the time is as yet too short to cause any agreement among operators as to the best co-ordination of insulation between line, transformers, breakers, and bus.

TRANSMISSION OF BULK POWER

Interconnection of large systems for bulk power interchange has continued which, with the hydroelectric-station development, has resulted in numerous 220-kv lines, the highest commercial voltage in the country being the 287 kv of the lines from Boulder Dam.[106] This interconnection of systems has caused further stability problems, which, together with the desire to reduce the damage caused by faults and lighten the effect on customers' services, has resulted in the development of high-speed relaying, both of the distance and balanced type, and the carrier-current and pilot-wire type; these types of relaying are being applied to transmission of all voltages. Relay times of one cycle or less are available, which, combined with five- or three-cycle breakers, give rapid clearing of faults where such extreme speed is necessary. To aid in permitting systems to ride through overhead line disturbances, the use of the Petersen coil, rapid reclosing of breakers, and discharge tubes is increasing.

The use of high-voltage cable for transmitting large blocks of power has increased, approximately 79 miles having been installed for 66 kv and above since 1933.

STATION AUXILIARIES

The majority of the steam additions to existing plants use electrical auxiliaries. Higher-pressure boilers have increased the demand for higher-speed boiler-feed pumps, and the trend is toward constant-speed or multi-speed motors for both this service and the forced- and induced-draft fans. Constant-speed squirrel-cage induction motors have been built as large as 2,000 horsepower for feed-water pumps and up to 700 horsepower in the wound-rotor type. Three-phase supply, 2,400 volts, is quite standard for this type of auxiliary, and the factory-built metal-enclosed bus structure is in general use, the lift type of breaker being popular. Air circuit breakers of the 5,000-volt 100,000-kva class are now available from several manufacturers for auxiliary station service, and as many consider it just as desirable to reduce oil contents of boiler rooms as of switch houses, the air breakers show increasing use. Noninflammable liquid, first applied to distribution transformers, is now used in power transformers and is particularly adaptable for auxiliary service in station locations where oil would be a hazard. More study is being made to ensure the continuity of auxiliary service, of obtaining separate sources of supply, and complete protection of auxiliary buses. The increasing use of pulverized fuel, with its intricate and delicate starting procedure, has introduced additional problems in

Table I. Government Hydroelectric Projects

Government Agency	Project	State	Ultimate Capacity (Horsepower)	Initial Capacity (Horsepower)	Installed Capacity (Horsepower)	Capacity on Order (Horsepower)
U. S. Bureau of Reclamation	Grand Coulee	Wash.	2,742,000	478,000		478,000
U. S. Engineer Corps	Bonneville	Wash.	665,000	137,000	137,000	148,000
U. S. Bureau of Reclamation	Shasta Dam	Calif.	515,000	412,000		412,000
Imperial Irrigation District	Drop 4	Calif.	26,600	13,300		13,300
U. S. Bureau of Reclamation	Boulder Dam	Nev. & Ariz.	1,835,000	515,000	752,000	230,000
U. S. Bureau of Reclamation	Elephant Butte	N. M.	34,500	34,500		34,500
U. S. Bureau of Reclamation	Casper-Alcova	Wyo.	45,000	45,000		45,000
U. S. Bureau of Reclamation	Green Mountain	Colo.	30,000	30,000		30,000
U. S. Bureau of Reclamation	Colo.-Big Thompson	Colo.	135,000	*		
U. S. Engineer Corps	Fort Peck	Mont.	100,000	*		
Platte Valley Public Power & Irrigation	Dist. Platte Valley	Nebr.	35,000	35,000	35,000	
Loup River Public Power District	Loup River	Nebr.	65,000	65,000	65,000	
Central Neb. Public Power & Irrigation District	Tri-County	Nebr.	54,000	26,000		80,000
Grand River Dam Authority	Pensacola Dam	Okla.	100,000	80,000		80,000
Lower Colo. River Authority	Buchanan Dam	Texas	51,900	34,600	34,600	
Lower Colo. River Authority	Tom Miller Dam	Texas	20,000	20,000		20,000
Lower Colo. River Authority	Inks Dam	Texas	16,000	16,000	16,000	
Tenn. Valley Authority	Norris	Tenn.	132,000	132,000	132,000	
Tenn. Valley Authority	Pickwick	Tenn.	330,000	110,000	110,000	
Tenn. Valley Authority	Wilson	Ala.	620,000	260,000	260,000	
Tenn. Valley Authority	Wheeler	Ala.	360,000	90,000	90,000	90,000
Tenn. Valley Authority	Guntersville	Ala.	136,000	102,000		102,000
Tenn. Valley Authority	Chickamauga	Tenn.	144,000	108,000		108,000
Tenn. Valley Authority	Hiawassee	N. C.	160,000	80,000		80,000
Tenn. Valley Authority	Gilbertsville	Ky.	350,000	*		
Greerwood County Power Authority	Buzzards Roost	S. C.	30,000	22,200		22,200
South Carolina Public Service Authority	Santee-Cooper	S. C.	213,000	*		213,000

* Work started, but no information on initial horsepower available.

continuity of service during system disturbances, and undoubtedly more thought will be given to either ensuring the maintenance of auxiliary-bus voltage or automatic starting of the pulverized-fuel equipment.

Hydroelectric-Plant Practice

Annual water-power figures are beginning to look like those for 1928 and 1929, predepression years. During 1938 about 750,000 horsepower of new capacity went into service, bringing the total capacity of water wheels to around 18,000,000 horsepower for the United States, as shown by figure 4. At the present time in the United States over 2,000,000 horsepower of water-wheel capacity is under construction and work has been started on other projects representing an ultimate installed capacity of 750,000 horsepower for which the power units have not yet been ordered.

A large part of this capacity is in plants being built by governmental agencies. There are, however, many projects being developed by public-utility and industrial companies, particularly in the northeastern and midwestern sections of the country. In 1937 and 1938 work was started or completed on over 60 of these projects, representing an initial capacity of 500,000 horsepower.

Notable among public-utility projects are the four 26,000-horsepower units for 110-foot head in the Claytor development of the Appalachian Electric Power Company on the New River, Virginia; the 77,000-horsepower unit for 188-foot head installed in the Kerr power house of the Rocky Mountain Power Company on the Flathead River in Montana; the 14,700-horsepower and the 8,400-horsepower units for 91-foot head in the Grandfathers Falls power house of the Wisconsin Public Service Corporation; and the 10,950-horsepower unit for 45-foot head being installed in the Solon development of the Central Maine Power Company. Several other projects have been put into operation or under construction by public-utility companies in Maine, Vermont, New York, Virginia, Wisconsin, and other states.

In point of installed capacity, water-power projects being built by governmental agencies exceed all others. These, including those that have been built and on which work has been started, represent an ultimate capacity of over 9,000,000 horsepower, or one-half of the total installed in the United States. Nearly 3,500,000 horsepower of this is for Bonneville and Grand Coulee plants on the Columbia River, 526,000 horsepower in California, and 1,835,000 horsepower at Boulder Dam (see table I).

These projects represent about two-thirds of the total ultimate capacity. Of the remaining third over 2,000,000 horsepower is represented by projects of the Tennessee Valley Authority on the Tennessee River, leaving only about 1,000,000 horsepower in other parts of the country. TVA projects include Wilson Dam plant with space for 610,000 horsepower, built before that organization was created by Congress.

By June 1939, only 1,631,500 horsepower had been installed in Government financed projects since 1932, and this includes 260,000 horsepower in Wilson Dam plant.

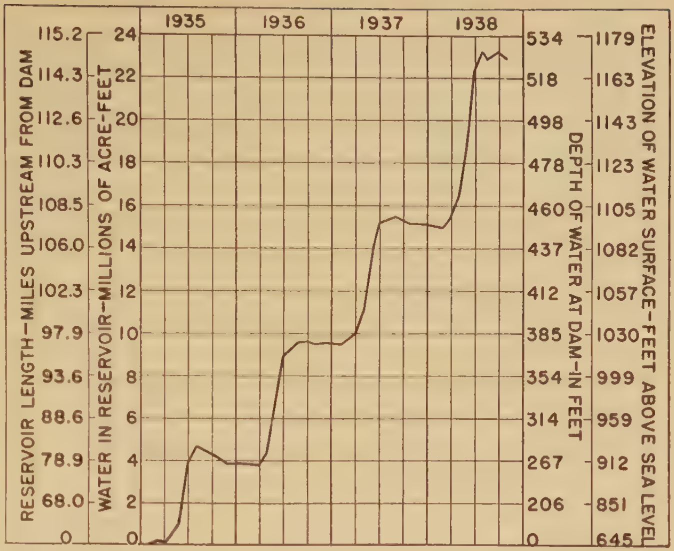

Figure 5. Rate at which Boulder Dam reservoir has filled since closing of the by-pass tunnels in 1935

For these plants there are on order machines having an aggregate capacity of 2,000,000 horsepower of which 1,250,000 horsepower is for Grand Coulee, Bonneville, Shasta, and Boulder plants, in sections normally supplied by water power.

Outside of Bonneville development, all the large governmental water-power developments in the Pacific Coast area are essentially water-supply and river-regulation projects from which large amounts of power can be generated, much of which will be required to pump water for municipal supply and irrigation. Grand Coulee is the largest of these and in fact is the largest in the world on which reliable data are available. It includes a straight concrete gravity-type dam 4,500 feet long, 553 feet high, and 500 feet thick at the base.

This dam will back the water up the river 150 miles to the Canadian border to form a reservoir with 9,645,000 acre-feet maximum storage and a maximum head of 360

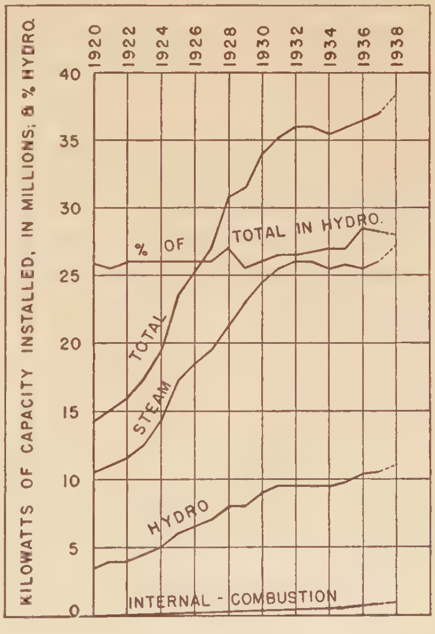

Figure 6. Growth of installed generating capacity in both privately and Government-owned public-utility plants of all classes in the United States

feet. A useful storage of 5,200,000 acre-feet will be available with 80 feet drawdown. At the midstream section of the dam will be a 1,650-foot spillway designed to pass 1,000,000 cubic feet per second. Between the ends of the spillway and the shores, two power houses will be built, each with nine 150,000-horsepower main turbines connected to 108,000-kw unity-power-factor generators. In addition, the west power plant will house three 14,000-horsepower service units.

Including the three service units, the total ultimate capacity of Grand Coulee plant is 2,742,000 horsepower, which is 900,000 horsepower more than planned for Boulder plant and 500,000 horsepower more than planned for the Beauharnois development on the Saint Lawrence River in Canada, which now has 483,000 horsepower installed.

Just above one end of the Grand Coulee dam and at right angles with it will be a pumping plant containing 12 vertical 65,000-horsepower synchronous-motor-driven pumps. Each pump will have a capacity of 1,000,000,000 gallons per day when pumping against a 295-foot head. These pumps will lift water from the main reservoir into a secondary reservoir formed by a dam across the lower end of the Grand Coulee, from where the water will flow to irrigate 1,200,000 acres of land. Six generators in the power house adjacent to the pumping plant will supply power to the pump motors. Three main generating units and two service units are now on order and are scheduled for initial operation in 1941.

Part of the power from the Shasta development now under construction on the Sacramento River in California will be used for pumping irrigation water. This project will have an ultimate capacity of 500,000 horsepower, of which four 103,000-horsepower units to operate under a 450-foot head are on order.

So much has been written about Boulder Canyon project that one hesitates to say more. But this project has so many interesting features that a report on water-power development would not be complete without calling attention to some of them. Construction work was started in 1931 and operation began in 1936. The project has four major purposes; namely, flood control, supply water for irrigation and municipal use, and power generation.

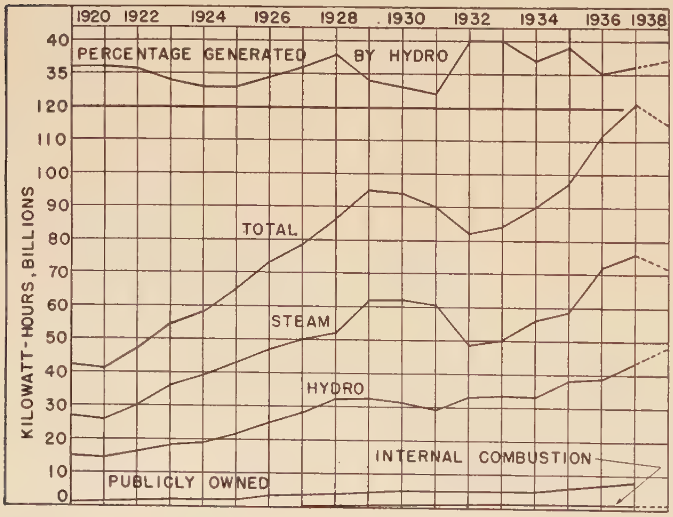

Figure 7. Growth of power generated in the United States in privately and Government-owned public-utility plants, and the relation between total generation and that produced by water power

In the power house, which is designed for an ultimate capacity 1,835,000 horsepower, 752,000 horsepower has been installed and two 115,000-horsepower units are on order. These will give this plant the largest installed capacity of any hydroelectric project in the world, and the only steam plant to exceed its present capacity is the Hudson Avenue station, Brooklyn, N. Y., which has 770,000 kw installed. Eventually, 400,000 horsepower of pumping load on the Metropolitan Water District aqueduct, running from the Colorado River to Los Angeles, Calif., will be supplied by Boulder Dam. Initial installation of this aqueduct goes into operation this year.

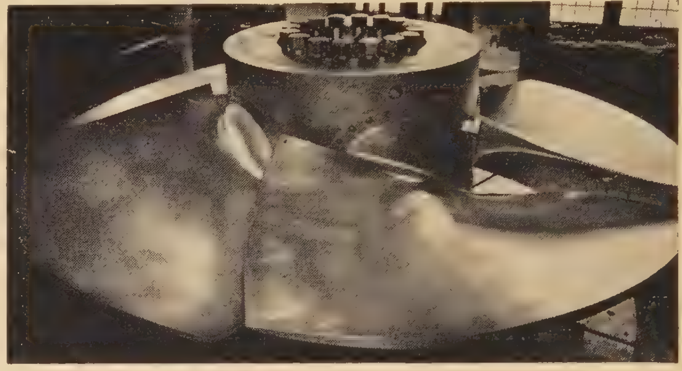

Figure 8. This 42,500-horsepower Kaplan-type propeller runner has its blade surfaces machined and polished all over

As figure 5 shows, Boulder Dam, which is 730 feet high and forms a reservoir of 30,500,000 acre-feet capacity, has prevented several floods that would have been disastrous on the lower river, and has also prevented irrigation-water shortages. The sharp rise in the curve each year during May and June shows how severe the floods are. Last year during this period 6,000,000 acre-feet of water was stored. This is equivalent to a continuous flow of 55,000 cubic feet per second for two months, in addition to the water permitted to flow down the river. If average water supply is obtained in the river this year the reservoir should be filled to capacity.

These water-power developments by governmental agencies naturally raise the much discussed question of hydraulic versus steam plants and what effect these new hydraulic plants are having on the relation of hydroelectric and steam-electric installed capacity and generation. In spite of all the activity in water-power development by governmental agencies, the growth in hydroelectric generating capacity was more rapid before 1932 than since then, when the Government seriously entered the field, as is evident from figure 4.

For example, for the seven years from 1925 to 1931, inclusive, installed water-power capacity increased nearly

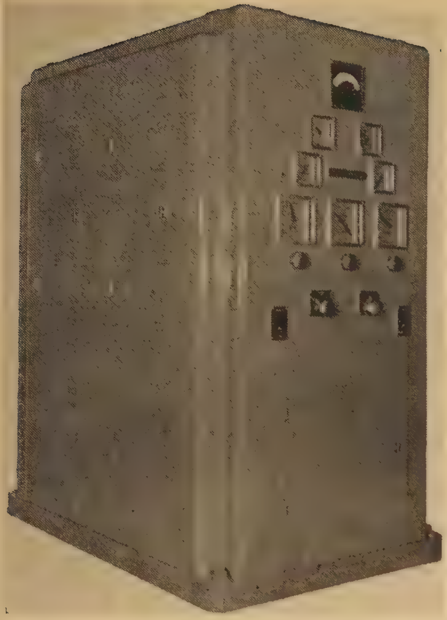

Figure 9. Modern type hydraulic-turbine-governing unit combines all parts of the governing system into a single cabinet with the exception of the servo-motors and generator for driving the actuator

5,500,000 horsepower, where from 1932 to 1938, inclusive, only 2,250,000 horsepower has been installed. Of course it must be admitted that the depressed condition of business has been a factor in the latter. But, if we compare only the three years from 1936 to 1938, inclusive, with the nine years from 1923 to 1931, inclusive, the latter shows a considerably steeper rise than the former. An even more important factor than the depression in slowing up water-power growth is that efficiency of steam plants has increased and their cost of construction decreased to where in many localities they now seriously challenge water-power developments on an economic basis.

An outstanding example of steam-plant construction in a water-power region is the new 160,000-kw plant of the Buffalo, Niagara and Eastern Power Corporation, being installed at Oswego, N. Y., in a region largely served by water power. Installation of this steam plant was not dictated by any shortage of water-power sites, for the company controls several within easy reach of where it is being built. When all factors were considered, economic and otherwise, the steam plant proved to be the most desirable. The city of Eugene, Ore., which operates its own power system and is only 160 miles away from the Federal Government's Bonneville hydroelectric plant, announced plans for a new peak-load steam or Diesel plant during the latter part of 1938. In 1937 the Tennessee Electric Power Company won the right from the State Public Service Commission to install a steam plant at Nashville, Tenn., by proving that this type of plant could supply power to its system more economically than it could be obtained from the Government-subsidized TVA hydroelectric system. Since then this plant has been sold to TVA.

Figure 6 shows the total generating capacity installed in all types of power plants operated by both privately and Government-owned utilities. Also the division of this capacity between steam, hydraulic, and internal-combustion-engine stations. A curve has also been added to show the relation that installed hydroelectric capacity bears to the total. This relation has remained remarkably constant since 1920. In this period installed hydroelectric capacity has increased only 2.1 per cent, or from 25.9 to 28 per cent of the total installed in all classes of plants.

Figure 7 shows power generated by the private and public agencies represented by figure 6. An interesting feature about these curves is that the per cent of total power generated by water power was practically the same (36 per cent) for 1937 as for 1920. Because of the total power load falling off sharply in 1938, and an abundant rainfall in practically all parts of the country, the per cent of water power showed an increase to about 37.5 per cent. These two factors, load growth or loss and rainfall, have a marked influence, and account for most of the peaks and valleys in the water-power curve. From the foregoing it is evident that as yet the relation between fuel-burning and hydraulic plants continues on a practically even keel. The curves in figures 4, 6, and 7 are plotted from data published by the Federal Power Commission, with the exception of 1938 for which figures published by *Electrical World* are used.

Even though Francis-type wheels have been built in unprecedented size and power during recent years, it is in the low-head field covered by propeller-type wheels where the greatest advancements have been made. This type of wheel, because of its high speed, has greatly reduced the cost of developing low-head projects. Al-

Table II. Large Propeller-Type Water Wheels Installed in the United States and Canada

Name of Plant	State or Province	No. of Units	Rating (Horsepower)	Effective Head (Feet)	Discharge (Cubic Feet per Second)	Type of Runner	Runner Diameter (Inches)	Speed (RPM)
Bonneville	Ore. & Wash.	2	66,000	66	12,000	Kaplan	280	75
Bonneville	Ore. & Wash.	2	74,000	66	14,400	Kaplan	280	75
Pickwick Landing	Tenn.	2	55,000	47	12,000	Kaplan	290	81
Wheeler	Ala.	2	45,000	48	9,000	Fixed blade	264	85.7
Safe Harbor	Pa.	6	42,500	55	8,000	Kaplan	220	109.1
Chickamauga	Tenn.	3	36,000	36	11,000	Kaplan		75
Guntersville	Ala.	3	34,000	36	10,000	Kaplan	265	69.2
Rock Island	Wash.	4	21,000	32	7,150	Manually adjusted blade	223	100
Louisville	Ky.	8	13,500	37	4,000	Fixed blade		100
Seven Sisters	Manitoba	3	37,500	66	5,700	Fixed blade	200	138.5
LaGabelle	Quebec	5	32,000	60	5,400	Fixed blade	195	120
Great Falls	Manitoba	6	28,000	56	5,000	Fixed blade	200	138.5
Chat Falls	Ontario & Quebec	8	28,000	53	5,300	Fixed blade	195	125
Island Falls	Saskatchewan	5	19,000	56	3,500	Fixed blade	145	163.6

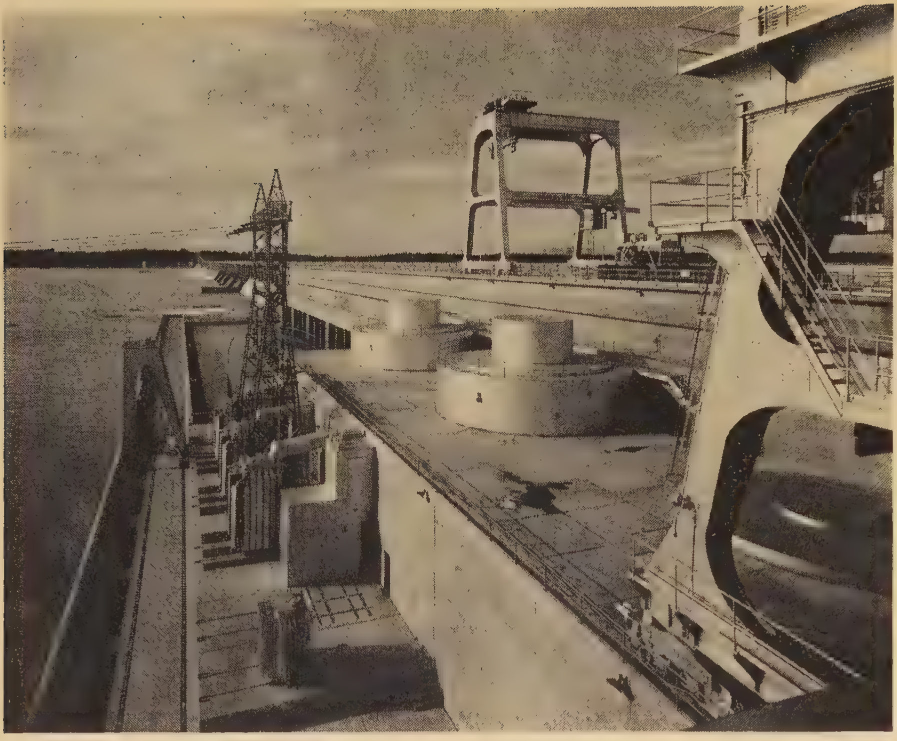

Figure 10. Outdoor-type plant at the Wheeler Dam project of the Tennessee Valley Authority has two 45,000-horsepower units, with space for six more

though developed less than 25 years ago, these units have come into wide use in both North America and Europe, in both large and small size. Table II gives data on some of the largest units installed in the United States and Canada. This type of wheel has been developed in three forms: fixed blade; Kaplan, the blade angle of which is adjusted by the governor; and the type on which the blade angle is automatically adjusted by change of water flow through the runner as the load changes. With the fixed blade design, its efficiency curve falls off quite sharply either side of maximum, but by adjusting the blade angle, high efficiency can be obtained over a wide range of load and head.

This type wheel has permitted an increase in specific speed from a maximum of about 90 rpm for a Francis-type wheel to 150 rpm and higher. Because of their higher speed, cavitation assumes far greater importance than with slower-speed runners, particularly for the larger-size units. This problem is handled in two ways, first by locating the runner at an elevation below tailwater level that will limit cavitation to what is considered a safe amount. Then in the construction of the runner vanes, the areas where pitting because of cavitation is expected are chipped out and these filled in with stainless steel by welding, after which in some instances the blades are machined all over, ground, and polished, as in figure 8. Any pitted areas that occur in operation are also chipped out and welded in with stainless steel. Experience has shown that stainless steel will stand the action of cavitation better than any other.

Welding is assuming an ever-increasing importance, not only in the maintenance of water wheels but also in their construction. For example, in the Bonneville propeller-type units, practically all parts, with the exception of the runners and shafts, were constructed by welding.

Governors for hydroelectric units have been improved in their ability to control speed and have been radically changed in appearance. Where a few years ago the actuator and valves were in one place, the oil-pressure pumps in another, and the pressure tanks in still another, the modern governor has these parts along with all instruments and indicators combined in a single unit, as in figure 9. On the front of this cabinet actuator are a speed and frequency indicator, draft-tube vacuum gauge, penstock-pressure gauge, duplex gauge showing generator-brake-system air pressure and brake-cylinder pressure, duplex gauge showing auxiliary and main relay valve port positions, speed-droop indicator with knob directly below, gate-limit and gate-position indicator with gate-limit knob directly below, speed-adjustment indicator with control knob directly below, manual generator-brake-valve control knob, control knob for transferring from main to auxiliary valve control and vice versa, cabinet-light switch and pilot lamp, emergency shutdown switch and pilot lamp.

Outdoor-type hydroelectric plants, which 10 or 15 years ago were attracting considerable attention, have been adopted in only a few installations. Wheeler Dam plant of TVA, figure 10, is an outstanding example.

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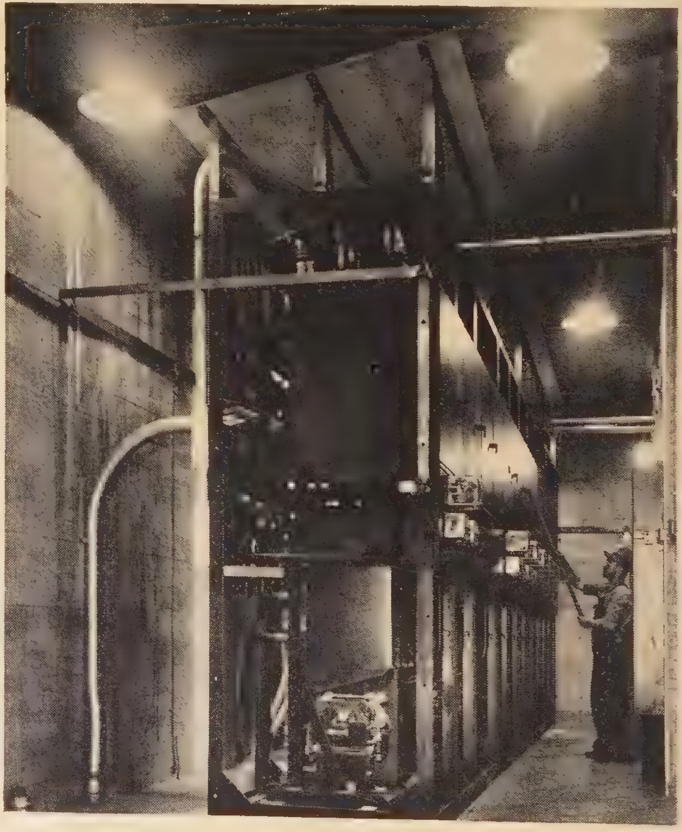
Air Breakers for Power-House Drives

A COMPACT GROUP of seven Westinghouse De-ion air circuit breakers, with interrupting rating of 13,850 amperes, controls the 3-phase 60-cycle 4,150-volt circuits for auxiliary drives serving a 200,000-pound-per-hour boiler and the 20,000-kw turbine at the Blount Street station of the Madison (Wis.) Gas and Electric Company. Based upon ten months' service, the maximum number of operations of any one breaker has been about 553 and the number of average automatic openings of all breakers 341.

These breakers were selected instead of conventional types because of: (1) greater safety; (2) elimination of oil storage, piping, and filtering equipment; (3) performance of more operations without maintenance; (4) reduction of inspection and repair expense; and (5) cleanliness. To date, maintenance and replacement of parts has been appreciably less than with oil breakers in comparable service. Because such air breakers can be placed close together without danger, the company was able to place them in a vault under the floor of the boiler room, as shown in the accompanying illustration. As a precaution, the top of the breaker structure is shielded by the slanted roof shown.



The Triple Alliance in Electrical Insulation

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MEMBER AIEE

A review of progress in electrical insulation achieved by the combined efforts of physicists, chemists, and electrical engineers

IF AIR were not an insulator, the generation, transmission, and utilization of electric power would be beset with almost insurmountable difficulties. For example, lamp sockets or any other exposed portion of the electric wiring in homes would support no voltage and would carry no current to lamps or other electrical appliances. In the powerhouse conditions would be even worse, unless perhaps the generators were placed in a high vacuum. If humans lived in a water medium, as fish do, the comforts electricity has provided almost certainly never would have been known. Perhaps the only advantage of a conducting medium would be the complete elimination of lightning, for then the clouds would not become charged. Conducting air, however, would be a high price to pay for removal of the danger of lightning.

In most respects air and several other gases are among the best insulators. In any practical sense the conductivity, power factor, and loss factor of air are zero when it is not stressed above its ionization voltage. Air, as the dielectric between the plates of a capacitor, is therefore used as the standard in all insulation testing. An air capacitor is the fundamental and basic element of any dielectric-loss or power-factor-measuring circuit in terms of which all materials are measured. But now one may be asked, "Why is there need for other insulating materials if air has such good properties?"

The answer is twofold: (1) The breakdown strength of air is somewhat lower than that of most liquid and solid dielectrics, and thus with air larger spacings between conductors are required; and (2) since air is a gas and therefore will support no weight, solid dielectrics are necessary to support the weight of the conductor. The breakdown strength of air at atmospheric pressure is 30 kv per centimeter when the electrodes used give a uniform field. This breakdown strength almost never is realized in practice, because uniform field conditions are rare and a factor of safety must be used.

The bare conductors of a 220-kv open transmission line are placed approximately 25 feet apart. In a power cable built for this same voltage, the thickness of oil-impregnated paper is less than $2\,^1/_2$ inches instead of the 25 feet of air. In the construction of any piece of electrical equipment from the largest powerhouse generator of well over 100,000 horsepower to the smallest electric-razor motor of less than $^1/_{100}$ horsepower, the space for insulation is limited. Hence, ever since the birth of the electrical industry a little over 50 years ago, the quest has gone on for new materials that would stand for longer periods of time a higher voltage per unit of thickness. The development of materials having not only high breakdown strength, but also the other desirable qualities of a good insulator—(1) low conductivity, (2) low dielectric loss, (3) low or high dielectric constant depending on application, (4) good mechanical properties, and (5) good thermal and time stability—has occupied the attention of many scientific and technical men. These men are physicists, chemists, and electrical engineers—the triple alliance in electrical insulation. Thus, problems of electrical insulation transcend the boundaries of several sciences.

History of Electrical Insulation

The early history of electrical insulation or dielectrics was made almost entirely by physicists. It began with the beginning of electrostatics in the 18th century and extended through most of the 19th century. With it we can associate such illustrious names as Franklin (1706–1790), Cavendish (1731–1810), Coulomb (1736–1806), Faraday (1791–1867), and Maxwell (1831–1879). Of these, Maxwell made theoretical contributions of the greatest importance and the others made equally important experimental contributions. These workers provided the background for the mass of work now reported in technical and scientific literature. Perhaps the first engineer to attract attention in this field was Siemens in Germany, who in 1864 observed that heating in capacitors was associated with a departure from the 90-degree phase relationship between alternating current and voltage. This was at the very beginning of electrical engineering, when telegraphy was the sole problem. The major work on dielectrics at that time was still being doing by physicists.

With the birth of the electric-power industry in the early 1880's, and with the realization of the advantages of high-voltage transmission which followed in the next ten-year period, more and more engineers became interested in dielectrics and their performance as insulators. The literature published since that time reveals an enormous amount of experimental data giving the electrical properties of many insulating materials together with scattered attempts to check or modify the older theories, particularly Maxwell's[1] theory of dielectric absorption. By 1900

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[1] For all numbered references see list at end of article.

most of the physicists had become distracted from the field of dielectrics through the discovery of X rays by Roentgen in 1895, the discovery of radioactivity by H. Becquerel in 1896, and the discovery of the electron by Sir J. J. Thompson in 1897, thus leaving the engineer to his accumulation of empirical data. The physicists saw greener pastures in these other fields and perhaps rightly so. However, they have never entirely deserted the field of dielectrics. At present, many physicists can be found doing important fundamental work on dielectrics.

Chemists may be said to have entered the field in 1912, when P. Debye[2] published his first paper on his theory of polar molecules. It was not until the 1920's, however, that this new fundamental theory received the attention that it deserved, undoubtedly because of the World War. It was then that chemists began to realize that much could be learned about the structure of molecules by measurement of dielectric constants and application of Debye's theory. The literature on both the experimental and theoretical sides began to develop rapidly and today this phase of dielectrics is of tremendous interest to chemists, physicists, and engineers.

In 1909, the synthesis of Bakelite was first described in a historic paper by Doctor Leo H. Baekeland.[3] Since that time, and more particularly since the 1920's, the organic chemist has synthesized new materials in the form of resins at an amazing rate. These have replaced to a large extent the natural resins formerly used in the electrical industry. Large quantities of these resins both in the form of solids and varnishes or impregnants for fibrous materials are used. Thus, physicists, chemists, and engineers all have contributed to the common knowledge of dielectrics. It is, therefore, not illogical to find representatives of all these branches of science working together in every important laboratory where dielectric research is carried on. This triple alliance is also well represented in a national organization, the Conference on Electrical Insulation of the National Research Council, with its subcommittees on chemistry and physics.

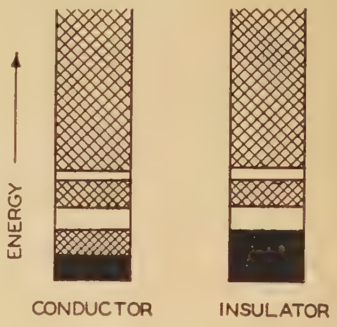
Much of the work that relates or might relate to dielectrics, however, is not done in laboratories where these three groups are working together, but in laboratories where only one group is working alone. Many chemists are working in laboratories synthesizing materials for almost every conceivable purpose. In other laboratories physicists and physical chemists investigate the structure and fundamental behavior of matter. These groups are not always familiar with electrical-engineering problems in the application of materials as insulators. A closer relationship of the various groups undoubtedly would promote more rapid progress.

Nature of a Dielectric

Perhaps the best definition of an insulator is that implied by Faraday when he segregated the materials then available into two classes according to whether they did or did not conduct electricity. On the basis of the well-established theory of matter, the important condition that makes a material an insulator or dielectric is that the electrons and other charged particles of which it is composed are held in equilibrium positions by certain forces characteristic of the material. When a field or a voltage is applied these charges are displaced, the negative charges in one direction and the positive in the opposite direction, so that the dielectric is strained elastically, so to speak. When the field is removed, however, all charges return to the original equilibrium positions. In a conductor, according to the electron theory of matter, it is presumed that the electrons are instantly free to move when a field is applied.

On the basis of the newer quantum theory, the difference between conducting and nonconducting crystals is explained by considering various zones of energy levels of valence electrons.[4] The energy spectrum for the valence electrons is illustrated in figure 1. The shaded regions are allowed and the clear regions are forbidden energies that an electron may have. The allowed energies correspond to finite, single-valued, and continuous solutions of the Schroedinger wave equation, whereas the forbidden energies do not correspond to finite, single-valued, and continuous solutions. The Schroedinger wave equation is the fundamental equation of wave mechanics. Conduction takes place in the crystal as a result of the transference of an electron from one energy level to another. This can occur only when not all of the energy levels in the shaded region are occupied by electrons. The black portion of the lowest shaded or allowed band in figure 1 indicates the presence of electrons. The diagram shows that the most important difference between a conductor and an insulator is that in the case of the former only part of all of the energy levels in the lowest allowed band are occupied by electrons, whereas in the case of the latter, all of the energy levels in this band are occupied by electrons. The mechanism of conduction in the two cases can be made clearer by the following rather crude analogy: The valence electrons may be pictured as bricks in a wall. In the case of a conductor the bricks are stacked only part of the way to the roof, the roof corresponding to the rather wide forbidden (clear) region just above the lowest allowed band of energies. Now when a small voltage is applied to a conductor, electrons are raised in energy from the black to the shaded region where they are free to move; that is, bricks are easily lifted from the top of the wall and moved horizontally. In the case of an insulator, however, the bricks corresponding to the valence electrons are stacked in such a way that the resulting wall extends to the roof or to the base of the forbidden region. In order for conduc-

Figure 1. Typical energy spectrum for valence electrons in a conductor and an insulator



tion to take place, a sufficiently large voltage must be applied to the insulator to raise the bricks through the roof or through the forbidden region to the next shaded or allowed band. It has been calculated that a voltage stress of approximately a million volts per centimeter is necessary to obtain an appreciable current in an insulating crystal such as sodium chloride. Breakdown of the crystal occurs when enough electrons are lifted through the forbidden region to produce an avalanche of electrons in the next allowed band.

The foregoing are only the physicist's pictures of a dielectric, and perhaps they are not completely truthful. They do, however, represent the limit of existing knowledge. Insulating properties of a material are not always determined by the kind of atoms in the material. All metals are known to be conductors or at least semiconductors; but mica, an excellent insulator, contains atoms of aluminum, potassium, and magnesium. The structure or manner of arrangement of the atoms within the material also has an important bearing on the dielectric properties.

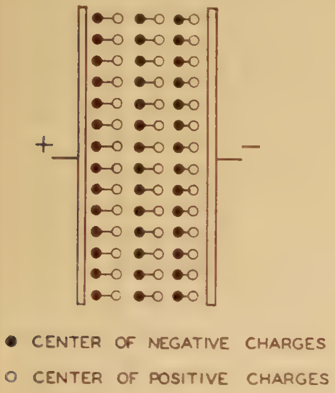


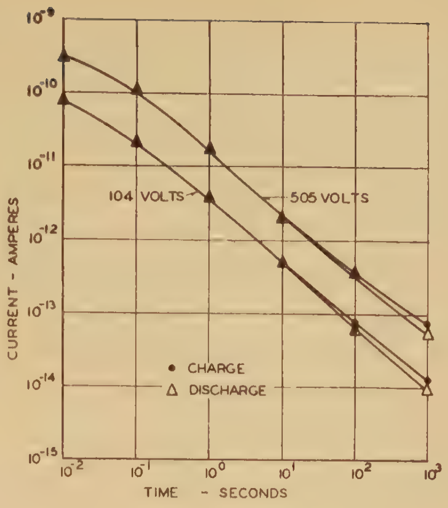
Figure 2. Dielectric between plates of a capacitor

All pure hydrocarbons are good insulating materials; but when, for example, oxygen is introduced into the molecule to form alcohols, ketones, or acids, the insulating properties are greatly impaired. The size of molecule often may influence also the electrical behavior. Phenol and formaldehyde in themselves have poor insulating properties, but when they are reacted with each other and subsequently polymerized, they form the very large Bakelite molecule which has long been used as an insulator. The oxygen, or rather the hydroxyl group in Bakelite, however, has some influence on its electrical behavior. The dielectric losses in this material are known to be higher than in the pure hydrocarbon resin styrene which has the lowest losses of all known resins. These points are discussed in more detail by Hartshorn and co-workers.[5]

Conduction, Loss, and Dielectric Constant

All insulators pass some current, however small, when voltage is applied across them. Gases perhaps should be excepted, because the conduction is almost immeasurably small below the critical ionization voltage. To see the nature of conduction in insulators, consider the somewhat crude picture of a dielectric between the metal plates of the capacitor shown in figure 2. The dielectric is divided into the fundamental structural units, which may be either atoms or molecules. Only a few of these units are shown in the much magnified picture. When a unidirectional voltage is applied, with the polarity indicated, the electrons are displaced instantaneously from the positively charged nucleus with which they are associated. This corresponds to an instantaneous current flow through the supply lines, which results in the charging of the capacitor. In gaseous dielectrics, this instantaneous flow of current takes place, but the current then falls to zero in an exceedingly short time and no further current can be detected, even with the most sensitive galvanometer.

Figure 3. Charge and discharge (d-c) for mica at two voltages (Voglis)



In solids, conversely, a current flow can be measured which decreases with time for minutes, hours, and in some instances even days after the voltage is applied, until the final constant conduction current is reached; it then persists indefinitely. This is illustrated in figure 3, which shows current curves for mica as obtained by Voglis.[6] From this figure, it is apparent that for the two charging voltages indicated the current is still decreasing after more than fifteen minutes and the final constant current has not yet been reached. The initial rush of current is not shown in figure 3, because it is over before even the 0.01 second at which time the measurement is begun. This decreasing current with time has been called "dielectric absorption" because it is believed that charge gradually "soaks" into the dielectric. The final constant current is true conduction current, probably of ionic nature, which flows through the dielectric.

Returning to figure 2, if the voltage is removed and the two plates of the capacitor connected together, thus discharging it, the instantaneous rush of current is in the opposite direction and the centers of the positive and negative charge again coincide. The absorbed charge flows out of the dielectric as illustrated in figure 3 by the discharge curves, and nearly all the charge absorbed on charging is returned on discharging. The charge and discharge curves deviate only at the long time end when the final conduction current becomes significant. This latter is, of course, not returned on discharge.

Maxwell[1] was the first to supply a mechanism for this phenomenon of residual or absorbed charge. He assumed that all dielectrics are heterogeneous and showed that volume charges can accumulate at the boundaries or inter-

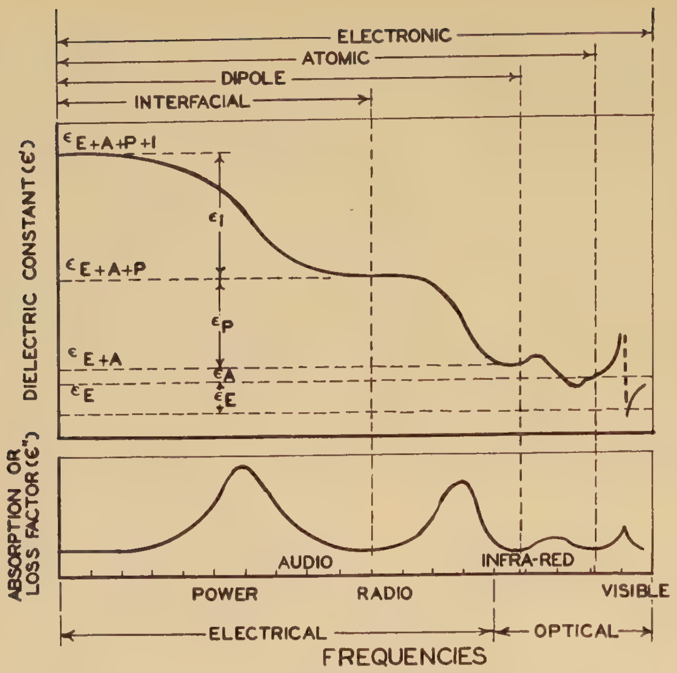


Figure 4. Schematic diagram showing variation of dielectric constant and dielectric absorption with frequency (Murphy and Morgan)

faces of the various components of the dielectric. This is a process that requires time. Maxwell probably pictured even slight impurities as heterogeneities. The fact remains, however, that even the purest solids, such as quartz, show dielectric absorption. Even to this day, nobody has found an explanation better than that given by Maxwell.

In liquids the action is somewhat different. On charge a current decreasing with time can be observed which gradually approaches a final constant value. On discharge, however, when the initial rush current is over, no further current is observed, thus indicating that dielectric absorption is absent. The decreasing current with time on charge is believed to be due to motion of ions or ion clusters, but practically nothing is known of the nature of the ions that are involved. An enlightening discussion of conduction in insulating oils is given by Whitehead.[7]

One of the most important characteristics of an insulator is dielectric loss under alternating current. This usually is measured by means of special bridge circuits in terms of power factor or loss factor. Power factor is defined as the ratio of the energy loss caused by oscillation of charges (or rotation in the case of polar molecules) in the dielectric to the product of volts applied and amperes flowing through the dielectric. Loss factor is the product of dielectric constant and tangent of the loss angle. Mathematically, power factor is defined as the sine of the loss angle. It is possible to compute the power factor approximately using the value of d-c conductivity corresponding to the time of half the a-c cycle. For 60 cycles this would correspond to the conductivity roughly 0.01 second after the application of voltage. A more exact method of computing power factor from the charging-current curve is given by Whitehead and Banos.[8] Power factor is important, not only in itself, but because it has a significant bearing on breakdown strength.

When a voltage is applied to a dielectric and a separation of charges takes place, the dielectric is said to be polarized. The amount of this charge separation is proportional to the dielectric constant. In an alternating field, the dielectric is alternately polarized in one direction and then in the opposite direction, thus bringing about an oscillation of charges.

There are several types of polarizations which are effective at different frequencies because these polarizations have different relaxation times. The instantaneous polarization discussed in connection with figure 2 is caused by the distortion of the orbital electrons with respect to the atomic nucleus and is called electronic polarization. If the dielectric is polar, there will be an additional contribution to the total polarization, because of the orientation of the polar molecules with the field. This is called dipole polarization. A third type of polarization is called atomic polarization, regarding which little is known. It may arise by the displacements of ions in an ionic crystal such as sodium chloride. The fourth and last type of polarization is that ascribed to heterogeneous dielectrics. Since it is believed to be caused by a formation of charge at the interfaces of the composite dielectric, it has been called interfacial polarization.

For each of these polarizations there is a frequency the period of which is too short for the particular polarization mechanism to respond. In this frequency region an anomalous dispersion or falling off of dielectric constant with increase in frequency takes place. The various dispersion regions are indicated approximately in figure 4 which also has been discussed by Murphy and Morgan[9] and Gemant.[10]

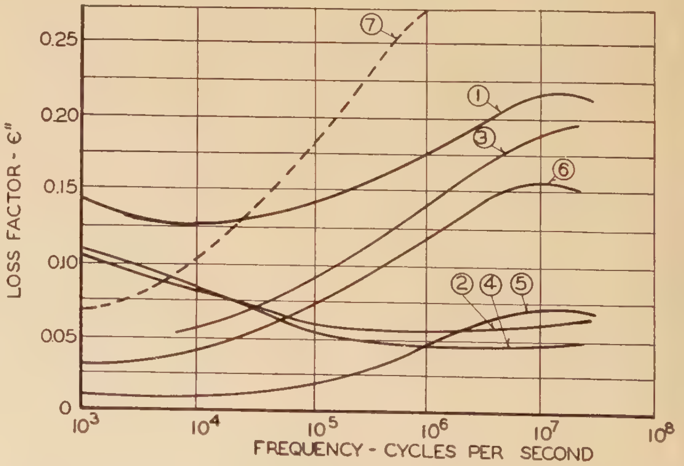


Figure 5. Loss-factor characteristics as a function of frequency for plastics, showing effect of cellulose molecules and mineral fillers (Yaeger)

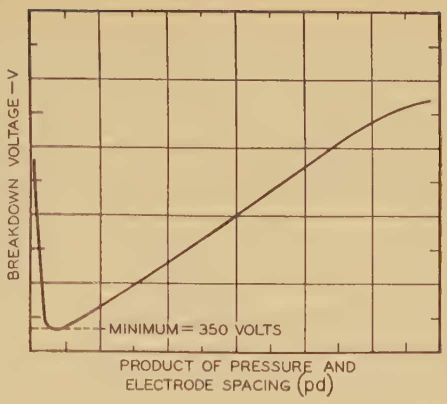
1—Urea formaldehyde containing cellulose filler
2—Unfilled phenolic resin
3—Phenolic resin containing 60 per cent wood flour
4—Phenolic resin containing mica dust or talc filler
5—Unplasticized ethyl cellulose
6—Laminated paper phenolic resin
7—Cellophane

The upper part of figure 4 shows that the slowest type is the so-called interfacial polarization. With this type of polarization may be included that caused by oscillation of electrolytic ions. It fails to respond beyond the audio-frequency region, the upper limit of which is approximately 20,000 cycles. Dielectric-constant dispersion may occur at any part of this region. Next is dipole polarization, which can respond from the upper radio frequency of about 10^8 cycles down. The frequency at which the dispersion occurs depends on the viscosity of the medium in which the dipole is rotating and on the radius of the molecule. The dispersion of atomic polarization for alkali halide crystals has been found to be in the infrared region as shown in figure 4. In the sense of any electrical frequency this is an instantaneous polarization. Electronic polarization covers the widest frequency range with the dispersion region in the optical-frequency range. The dielectric constant for electronic polarization can be computed from refractive index measurements by the use of Maxwell's law ($\epsilon = n^2$) which states that the dielectric constant equals the square of the refractive index. For many materials such as the pure nonpolar hydrocarbon liquids the dielectric constant indeed can be approximated by squaring the refractive index. For such materials the dielectric constant obviously is independent of any frequency in the electrical range, and the polarization is almost entirely electronic.

The lower part of figure 4 shows that a maximum of energy loss is associated with each dispersion region shown in the upper part of the figure. These manifest themselves as power-factor maxima in the electrical-frequency range and as absorption regions in the infrared and optical-frequency range. This has the obvious practical significance that a material should not be used in the frequency region where the energy-loss maximum appears. An example of this is found in the work reported by Yaeger.[11] He has measured the loss factor and dielectric constant of a number of plastics over a range of frequency from 10^3 to 3.5×10^7 cycles. He found that when cellulose is incorporated in the resin in whatever form, such as wood flour and paper or cellulosic resin, a loss factor maximum appeared at approximately 10^7 cycles. Some of Yaeger's results are shown in figure 5. A dielectric-constant dispersion was observed at the same frequency, but is not shown. Figure 5 shows also that when such mineral fillers as mica dust and talc are added, the maximum does not appear. The dashed curve (7) of figure 5 is for Cellophane as obtained by Stoops,[12] and is added to show that this cellulosic material also appears to have a maximum at the same frequency. The explanation offered for the loss-factor maxima in cellulose derivatives is that the hydroxyl groups rotate about the long cellulose chain, and for this rotation 10^7 cycles is the characteristic frequency. The practical significance is that cellulose derivatives should not be used as very high-frequency insulation.

This discussion might be carried much further. The properties of conductivity, dielectric loss, and dielectric constant have been discussed only in the most general way. The dielectric constant behavior of polar molecules has been and still is of much interest to the chemist and physicist because of the relation between dielectric constant and molecular structure. But the insulation engineer also is extremely interested in these matters.

Figure 6. Breakdown strength as a function of product of pressure and electrode spacing



Electric Breakdown or Dielectric Failure

Breakdown strength is perhaps the most important property of dielectrics. It has been investigated chiefly by engineers and physicists. The subject is far too large to be adequately treated in a discussion of this kind, and hence only a cursory examination of the state of existing knowledge is given here. Unfortunately, little is known of the mechanism of breakdown of liquids and solids mainly because of the lack of intimate knowledge of the liquid and solid states. With the quantum theory physicists are renewing their attack on the solid state in particular, and any information which the atomic physicists obtain will be helpful. Because of the greater distances between atoms or molecules in gases, knowledge of the conduction and breakdown mechanisms for these materials is much greater than for the more condensed states of matter. The theory for gases is fairly well developed. Knowledge of liquids and solids is based almost entirely on experimental data.

In gases there are always positive and negative ions which number about 600 per cubic centimeter each for ordinary air.[13] With the application of voltage these are accelerated and make collisions with neutral molecules. As the breakdown voltage is approached these collisions become severe enough to rupture neutral atoms, thus forming other charged particles. This process goes on in a cumulative way and breakdown results through the initiation of a self-maintained discharge. Townsend[14] has expressed the current produced in this ionization-by-collision phenomenon by means of an exponential, thus illustrating its cumulative nature.

Another important relation describing breakdown in gases is Paschen's[15] law, which states that the breakdown strength of a gas is proportional to the product of the distance between electrodes and the pressure; or for fixed electrode spacing, the breakdown strength is proportional to the pressure. Since the mean free path of the atoms or molecules in a gas is inversely proportional to the pressure, this is equivalent to saying that the breakdown strength is inversely proportional to the mean free path. The experimental data are illustrated in figure 6. Apparently

Paschen's law is valid for the intermediate region. At a certain low value of pressure, the curve has a minimum and for air this minimum breakdown strength is approximately 350 volts. This occurs at a pressure of a small fraction of a millimeter of mercury. As the pressure is lowered below the critical value, the number of molecules becomes so small that even though the mean free path becomes large, the probability of ionization by collision is small. It is well known that a high vacuum has an extremely high breakdown strength limited only by electron emission from the electrodes. For ordinary electrode spacings the upper limit of the validity of Paschen's law is approximately ten atmospheres pressure. Above this, the curve begins to flatten out because of space charge and electrode effects. Some recent work on the breakdown strength of compressed gases is described in a paper by Howell.[16]

Passing now to solids and liquids, von Hippel[17] has shown that Paschen's law for gases cannot be extrapolated to explain the behavior of these condensed insulators. Assuming breakdown strength of air to be 30 kv per centimeter and average density of liquids and solids to correspond to about 2,000 atmospheres pressure, solids and liquids should stand about 5×10^7 volts per centimeter. Experimental values for such insulators, however, lie in the range of 10^5 to 10^6 volts per centimeter. An attempt to explain this discrepancy has been made by von Hippel[17] in a theoretical and experimental study of ionic crystals such as the alkali halides. He concluded that breakdown in the alkali halides is electronic and that the mechanism of cumulative ionization is different from that in gases. He concluded further that cumulative ionization creates space charges which distort the field and that these space charges play a dominating role in the breakdown of solids and liquids. As an illustration of the disagreement among those working in this field, the work of Inge and Walther,[18] who also made a study of electric breakdown of alkali halide crystals, may be cited. They studied the breakdown strength over a range of temperature and found that it decreased markedly with increase in temperature. They conclude that breakdown in alkali halide crystals is not electronic, at least at the higher temperatures, and give evidence in support of heat breakdown.

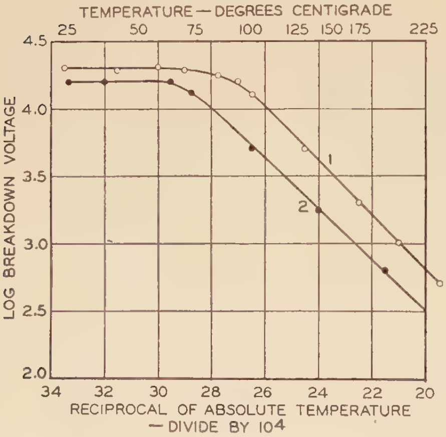


Figure 7. Influence of temperature on breakdown voltage for two glass samples (Inge and Walther)

1—Resistivity at 200 degrees centigrade 2.09×10^7

2—Resistivity at 200 degrees centigrade 4.06×10^6

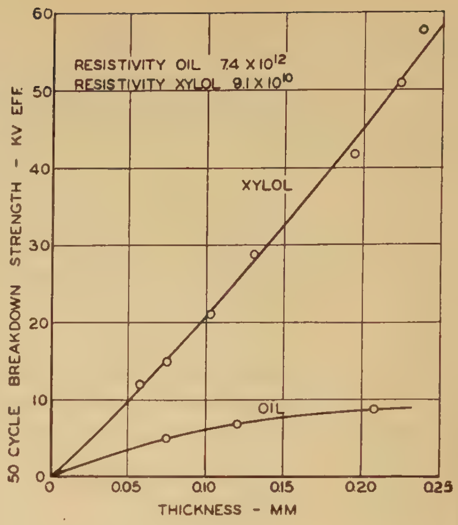


Figure 8. Breakdown versus thickness of glass showing influence of testing medium (Inge and Walther)

The theory for heat breakdown was originally developed by Wagner.[19] He assumed that one part in the dielectric has a higher conductivity than all other parts and by the following reasoning shows that breakdown should take place at the point of highest conductivity: Heat is generated at the high conductivity point at a faster rate than it can be dissipated, and because of the positive temperature coefficient of conductivity in dielectrics, this results in cumulative heating. Once cumulative heating is established the dielectric must fail, for it is literally melted or burned because of the high temperature developed in this way. The theory undoubtedly explains the breakdown of solids in a qualitative way, particularly in high-loss materials or at high temperatures. On the basis of this theory, one would expect a decrease in breakdown strength with increase in temperature and also with increase in conductivity and dielectric loss. That this is true has been demonstrated by Inge and Walther[20] in their work on glass. Their curves for two glasses of different resistivities are given in figure 7 in which the logarithm of the breakdown voltage is plotted against the reciprocal of absolute temperature, showing that at low temperatures the breakdown strength is independent of temperature. In this region the breakdown is believed to be disruptive, that is, the forces of cohesion between atoms or molecules are overcome. In the high-temperature region, the logarithm of the breakdown strength may be seen to decrease linearly with the reciprocal of the absolute temperature. In this region heat breakdown prevails. Intermediate between these two there is a transition region where both effects apparently enter into the breakdown process.

Figure 7 shows also that the glass with the higher resistivity has the higher breakdown strength. This is true in general, and particularly of solids. It should now be evident why engineers insist on low-conductivity or low-power-factor materials for use as high-voltage insulators.

It is well known that the apparent breakdown strength of insulation decreases with increase in thickness of the sample under test. This is caused by the voltage stress concentration at the edges of the electrodes. The sharper the edges of the electrodes the greater the nonuniformity of the field and the lower the apparent breakdown strength.

It has long been known that this edge effect can be suppressed and that then the breakdown strength increases linearly with the thickness. One way to suppress the edge effect is to use a test sample in the form of a double concave lens with spherical electrodes fitting the concavities. This results in a thicker layer at the edges which assures breakdown at the bottom of the spherical cavity where the field is uniform.

Another method of suppressing edge and contact effects is that used by Inge and Walther,[21] and consists in immersing the test specimen in xylol. The effectiveness of this method is illustrated in figure 8. It shows that when the usual low-conductivity oil is used as the medium surrounding the test specimen, the breakdown strength is far from linear with thickness, but when the higher conductivity xylol is used, a linear relation results. The higher conductivity of the xylol effectively removes the stress concentrations. The same effect can be accomplished by adding a small proportion of acetone or aniline to transformer oil.

It should be easy to see why there is usually so much discrepancy in breakdown tests on the same material when the testing medium can influence the results as much as 500 per cent. Still other effects have a marked influence, of which perhaps nonuniformity of the test specimen is most serious. For liquids the situation is still more complicated. A drop of water, a fiber or dust particle drawn between the electrodes can markedly influence the breakdown. For both liquids and solids the rate of rise of voltage is also important. So many factors can affect the breakdown that a test result without a statement of test conditions has little meaning.

Stability of Insulators in Service

In general the weakest portion of electrical equipment is the insulation, because insulators are comparatively fragile and more susceptible to deterioration than other materials entering into the construction. Unfortunately, also, most insulators are organic, which places a serious temperature limitation upon them. The ability of a material to maintain good insulating properties over a long period of time under service conditions thus becomes extremely important. "How long will the material last?" is a question often asked. To answer it engineers have devised many types of accelerated life or aging tests, where temperature or voltage or both are elevated above normal in order to obtain results in a reasonable time. The problem of interpreting such test results in terms of service life has been exceedingly difficult.

Where inorganic insulators such as mica and fiber glass can be used this problem is somewhat simplified; but even here the flakes of mica and the glass fabric must be bonded together or filled with an organic material having a definite temperature limit. The recent development of glass textiles[22] represents an important contribution to the insulation field, but a still more important contribution is yet to be made, namely, the development of an inorganic plastic bonding material with electrical properties comparable with those of the low-alkali glasses and mica.

As has been indicated already, most insulations are organic, and most of these take the form of cellulose, petroleum oils, and resins or varnishes. All three are used in the transformer and the first two in high-voltage cables. Oil and cellulose often are combined because they not only possess excellent electrical properties, but also very desirable mechanical properties. The two in combination and each alone have been the subject of many investigations by both chemists and engineers. The noteworthy improvement in the performance of oil-impregnated paper as a high-voltage insulation is in no small measure due to such important work as has been done by Whitehead[23] and his co-workers. Much of this work, however, has been of a physical nature, and if further rapid progress is to be made the services of the chemist appear indispensable, for insulation deterioration is to a large extent a chemical problem.

Cellulose, reasonably free of impurities, possesses good thermal stability. Since it is a porous material it cannot be used alone, but must be filled with some material that will replace air and prevent the entry of moisture. Considerable evidence has been supplied recently that most of the deterioration of cellulose is caused by the products of deterioration of the impregnant. An example of this effect is found in the work of Clark[24] who made accelerated stability tests on paper impregnated with various oils. Figure 9 shows some of his results with a normally refined oil and a highly refined oil. The power factor of the latter is seen to increase very rapidly, which is probably caused by the increase in acidity of the oil combined with the effect of this acidity on the paper. The normally refined oil builds up no acidity during the test and no serious increase in losses is noted.

In the application of materials as insulators, the maintenance of good mechanical properties for long periods of time often is quite as important as a similar maintenance of good electrical properties. That the mechanical properties of cellulose can deteriorate very rapidly and seriously when aged in oil exposed to air is shown in figure 10

Figure 9. Dielectric instability of linen paper impregnated with highly refined oil (Clark)

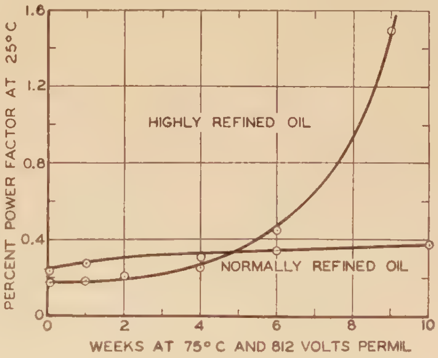
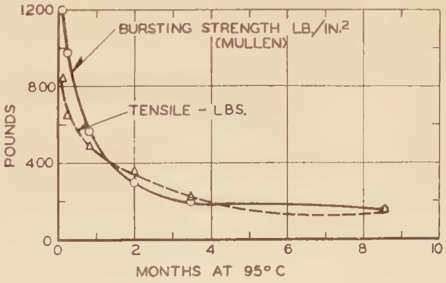


Figure 10. Deterioration of the mechanical properties of fuller board in oil open to air (Hill)



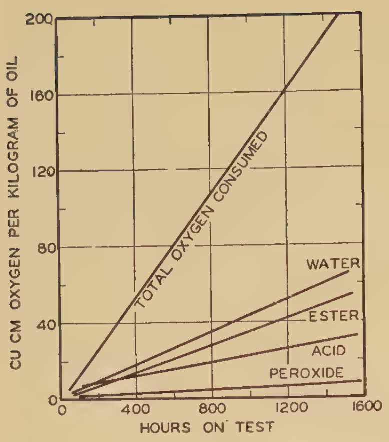


Figure 11. Oxygen balance for oil aged in closed vessel (Larsen)

taken from a recent paper by Hill,[25] in which temperature limits are discussed. Strong evidence that products of oxidation of resins may also destroy the mechanical properties of cellulose is given by Weber.[26] He shows that this action on cellulose can take place even at room temperature over a period of years. It appears, therefore, that much of the deterioration of cellulose is caused by the impregnant. The mechanism by which this secondary deterioration of cellulose takes place has not as yet been fully explained. The deterioration of cellulose in itself and the effect of impurities also require further study.

In the study of deterioration of petroleum oils, two important effects have been isolated. One is the effect of oxygen on the oil, and the other the effect of electrical discharge. Much research effort has been expended on the study of oxidation of petroleum oils, and perhaps this has been out of proportion to the progress made. These studies have been difficult because of the complex nature of petroleum. So far the oxidation mechanism is still a matter of speculation. One of the more important current researches on oils is that being carried out at the Massachusetts Institute of Technology. A similar work on the combined behavior of cellulose and oils under electrical stress is being carried out at The Johns Hopkins University. Both of these projects have received wide industrial sponsorship. The former[27] involves a fundamental study of oils having a wide range of chemical constitution. Citing only one phase of this work, Larsen[28] has found that the Grignard reagent used in conjunction with other tests makes possible the evaluation of the oxygen balance for oils; that is, the part of the total oxygen consumed that enters into each type of product. A typical case of this is given in figure 11, from which water is seen to be one of the most important products of oxidation. This, together with the fact that water can affect the electrical properties more than some other oxidation products, has not always been appreciated.

Returning to the effect of electrical discharge on oils, it may be said that considerable progress has been made in recent years toward explaining the phenomena. Electrical discharges arise in oil-impregnated-paper insulation through the formation of gaseous pockets as a result of normal temperature cycles and accompanying expansion and contraction. The electrical discharge formed in these pockets is an abundant source of ions which under the influence of the field bombard the oil molecules. The products are usually hydrogen, hydrocarbon gases, and waxy solid polymerization products known as "X-wax." It has been shown that the degree of refining of the oil strongly influences the amount of gaseous products given off by an oil.[29] In figure 12, the pressure rise in a closed system is plotted against time of subjection to an ordinary low-pressure electrical discharge. It may be observed that the highly saturated solvent-refined oil gives off considerably more gas than the highly aromatic extract obtained in solvent refining.

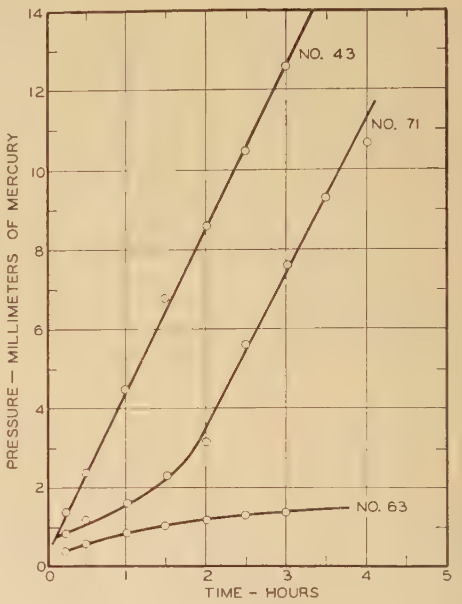
The refined saturated oils, however, possess good stability to oxidation and hence are desirable from this standpoint. The addition of small amounts of certain aromatic hydrocarbons decreases markedly the amount of gas given off by saturated oils.[29] This is illustrated in figure 13, which shows the effect of adding diphenyl to a solvent refined oil. Such methods, while valuable as palliatives in prolonging the life of insulation, do not represent a complete solution of the problem. So far no derivative of petroleum has been isolated that is either entirely stable to oxidation or immune to the effects of electric discharge.

Figure 12. Gas evolution under electric discharge as influenced by degree of refining

No. 43 — Highly saturated solvent-refined oil

No. 71—80 per cent solvent-refined oil plus 20 per cent solvent extract

No. 63—Highly unsaturated solvent extract



A striking example of the results of chemical effort expended in the field of insulation is the development of synthetic liquid dielectrics. Some years ago a demand arose for fireproof insulating liquids for use in certain hazardous installations of electrical apparatus. Fortunately, this demand came at a time when the necessary basic hydrocarbons, namely, the benzene derivatives, were available as by-products in the chemical industry. When this problem was placed before the chemist, he soon recognized the inherent stability of these benzene derivatives and that they could be made noninflammable by replacing a sizable fraction of the hydrogen atoms with halogen atoms. The physical properties required for various applications were obtained by properly blending the various halogenated benzene derivatives. Some of the compounds used are chlorobenzene, chlorodiphenyl, and alkyl chlorobenzene; the number of chlorine atoms in each may vary somewhat. These materials, however, have replaced only a small part of the petroleum oils used in transformers. Their cost is still high compared with that of petroleum. Chemical history, however, has shown repeatedly that cost reduction in synthetic products is merely a matter of time.

Halogenated hydrocarbons incidentally have found a more important use as an impregnant for the paper dielectric used in capacitors. The dielectric constant of oil-impregnated paper formerly used is approximately 3 and that of paper impregnated with these synthetic liquids is about 4.5. This higher dielectric constant combined with the discovery that these synthetic liquids enable operation at higher voltage stresses, has enabled engineers to reduce the physical size of capacitors to half that of earlier capacitors with oil-impregnated-paper dielectric. Operation at higher voltages is made possible by better voltage distribution between impregnant and paper. For two materials used in such a combination the stress divides itself in the inverse ratio of dielectric constants. The dielectric constants of cellulose fiber, halogenated hydrocarbons, and oil are approximately 6, 4, and 2.2 respectively. Thus, in oil-impregnated paper the oil bears several times as much stress as the paper fibers, which is not an ideal condition. The voltage distribution becomes better when the oil is replaced with the polar liquid having a dielectric constant more nearly equal to that of paper.

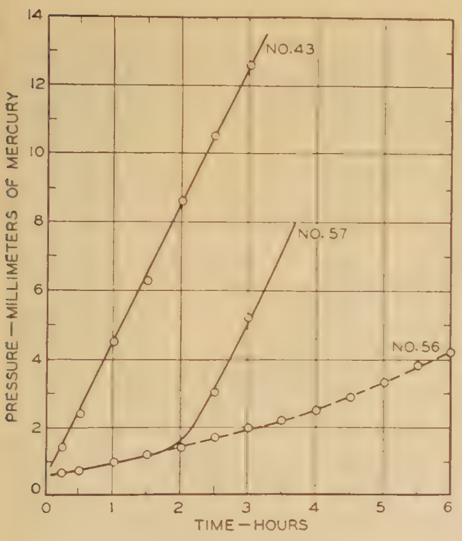


Figure 13. Gas evolution under electric discharge showing effect of adding diphenyl to oil

No. 43—Saturated solvent-refined oil at 27 degrees centigrade

No. 57—Oil plus 5 per cent diphenyl at 27 degrees centigrade

No. 56—Oil plus 5 per cent diphenyl at 60 degrees centigrade

The dielectric properties of these chlorinated hydrocarbons have been investigated extensively. Figure 14, taken from a paper by Hill,[30] illustrates beautifully the power-factor and dielectric-constant behavior as influenced by temperature and frequency that is typical of polar materials. At low temperatures the material is too viscous for the permanent dipoles to rotate, and the dielectric constant is essentially that corresponding to the electronic polarization. As the temperature increases the polar molecules begin to rotate more and more freely because of the lower viscosity until the maximum contribution is reached. As the temperature is further increased, however, the thermal motion of the molecules acting as a restoring force disturbs the orientation of the dipoles. This effect increases with the temperature in accordance with the Debye theory and explains the slow decrease in dielectric constant. Very sharp power-factor maxima are observed in the dielectric-constant dispersion regions. These maxima are shifted to higher temperatures as the frequency increases. The 60-cycle power-factor may be seen to increase again above 60 degrees centigrade. This is caused by the oscillation of ions which are presumably of an electrolytic nature. No similar increase in power factor is observed at 1,000 cycles because these ions are of such size that they no longer can follow this high frequency. Obviously, any practical liquid for capacitors is always blended so that the dielectric-constant dispersion and power-factor maximum are below the operating temperature.

Liquids of this type with even higher dielectric constant and greater stability are desirable. In the case of solids, resins are sought that combine good electrical properties with stability at higher and higher temperatures. Organic materials appear to have a definite upper temperature limit and even the best of them fail when subjected continuously to temperatures as high as 150 degrees centigrade. With present trend toward higher temperatures, either increasing use must be made of inorganic insulators or the temperature stability limit of organic materials must be raised. In order that the former may be fully accomplished, a suitable inorganic plastic material must

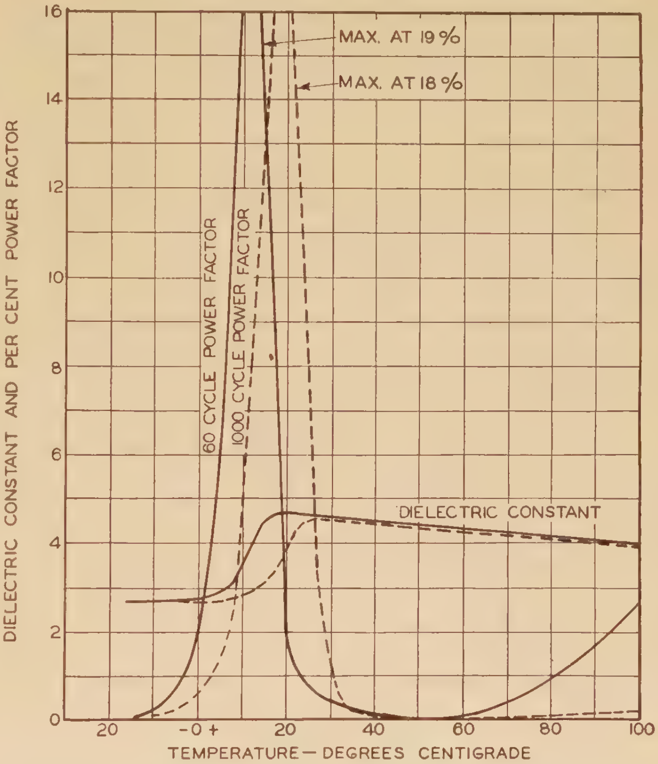


Figure 14. Typical behavior of power factor and dielectric constant of a polar dielectric liquid (Hill)

be developed. Whichever path is chosen, the chemist holds the key to the solution. The engineer can only tell him when he has arrived at the proper solution. Co-operation between engineer and chemist undoubtedly will hasten progress.

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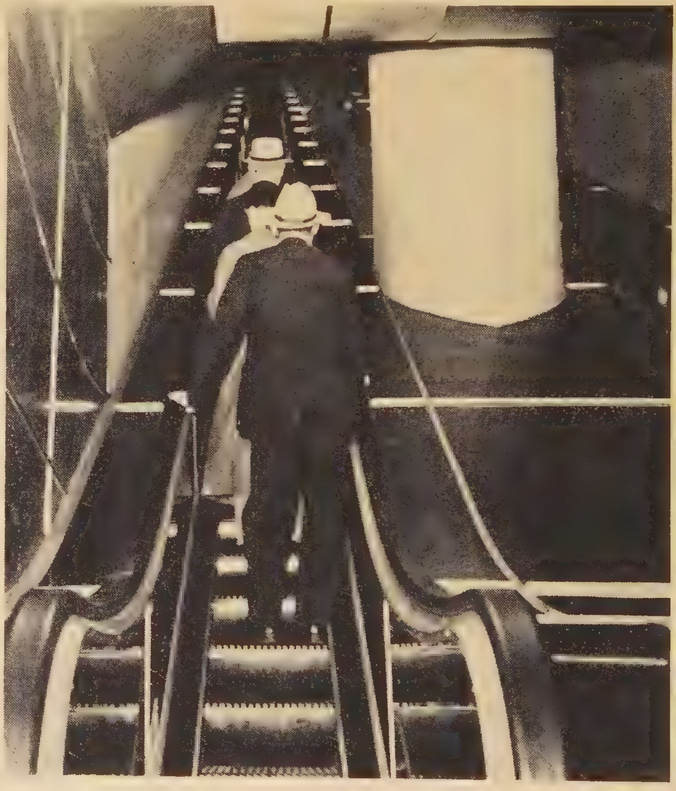
Interior Transportation at the New York World's Fair

FOR temporary buildings, an unprecedented amount of equipment for vertical and horizontal transportation has been provided in the exhibit buildings at the New York World's Fair. Thirteen exhibits have among them 21 elevators and 16 electric stairways. General Motors Building has three elevators and four electric stairways, and the spectator conveyer for the "Futurama" (see article in December 1939 issue). The French Building has five elevators and four electric stairways; the Russian Building, five elevators and two electric stairways; the Theme Building, two electric stairways, one of them the longest in the United States. The American Telephone and Telegraph Building and the Westinghouse Building each have two electric stairways, and the Italian Building has two elevators. Six other buildings—British, Ford Motor, Petroleum Industry, Rumanian, United States Government, and World's Fair Headquarters have one elevator each. The Ford Motor Company also offers direct transportation through part of its exhibit by automobile.



This electric stairway in the Theme Building at the New York World's Fair has a travel of 120 feet and is said to be the longest one in America; it was built by Westinghouse as was the 96-foot one at the right of it

All this interior transportation, with the exception of the Ford cars, represents a total investment of nearly $800,000. The 16 electric stairways alone have a combined maximum one-way capacity of over 90,000 passengers per hour.

Current Progress in Electrical-Insulation Research Reflected at NRC Conference

Recent progress in various phases of electrical insulation research was reflected in the 26 progress reports informally presented at the 12th annual meeting of the Conference on Electrical Insulation of National Research Council, held November 2–4, 1939, at Cambridge, Mass., and reported briefly in the December issue, page 526. One of the four sessions was devoted to chemistry and physics; one to measurements; and two to materials. As was true of last year's sessions, the emphasis was on research in the fundamentals of electrical insulation rather than on applications to practice, although the Conference continued in its unique position of effectively bringing together the active representatives of both the scientific and the "practical" groups interested in the general subject. Brief abstracts reflecting the high lights of the various reports presented are given on this and the following three pages, all based upon abstracts prepared by the respective authors.

Chemistry and Physics

Mineral-Oil Deterioration: Study of Systems and Test—*J. C. Balsbaugh* (*A'23, M'35*), *A. H. Howell* (*A'35*), *A. G. Assaf.* An improved deteriorating system for use in the study of insulating oils has been built having the following features:

1. All-glass system, approximately one liter volume, including a pump for mechanical agitation of the sample and gas dispersion through the sample.
2. Mechanism for automatically maintaining the absolute pressure.
3. Platinum cell for making electrical measurements on the sample during deterioration and without withdrawing test samples from the system.

A series of tests to determine the effect of heat on an oil sample in the presence of nitrogen, the sample being one having a relatively high oxygen content as measured by the Grignard apparatus, the test being carried on with the (*a*) oil alone, (*b*) oil and paper, (*c*) oil and copper, and (*d*) oil, copper, and paper gave the following results (test 335 hours, 110 degrees centigrade; 1,000 hours, 125 degrees centigrade):

1. The power factor of the oil, in the test with oil and paper, decreased slightly with time.
2. The power factor of the oil, in the test with oil by itself, increased slightly with time.
3. The power factor of the oil, in the test with oil, copper, and paper, increased fairly rapidly at first and then at a decreased rate.
4. The power factor of the oil, in the test with oil, copper, and paper, increased rapidly at first to a high value (within 300 hours) and then remained substantially constant.

A relatively large number of light-absorption measurements over the visible range of the spectrum have been made on a series of oils deteriorated by oxidation, both on the oil by itself and on the oil in the presence of copper, at different amounts of oxygen absorbed by the oil. These tests, in general show (volatile products removed during oxidation):

1. The number of absorbing molecules is linearly related to the oxygen absorbed by the oil.
2. The more highly refined oils show a decreased number of absorbing molecules for a given amount of oxygen absorbed by the oil.
3. The presence of copper during the oxidation gives a decreased number of absorbing molecules for a given amount of oxygen absorbed.

Electrical Properties and Densities of Bromo Substituted Aliphatic Acids in Benzene and Dioxane Solutions—*E. J. Van Loon, H. C. Ott, O. M. Arnold.* As part of the investigation of various acids and their derivatives, the dielectric constant at 1,000 kilocycles and density of solutions of α bromo derivatives of propionic, n-butyric, iso-butyric, n-valeric, and n-caproic acids in benzene and dioxane were determined at 25 degrees centigrade. The molar polarizations of the acids in solution were calculated for the different concentrations studied. The lowest concentrations observed were about 0.01 mol fraction of solute. The dipole moments were calculated by neglecting the atomic polarizations. As with unsubstituted acids, the brom-acids are evidently largely associated in benzene, even in dilute solutions, and hence the polarization is much lower than would be shown by single molecules. In dioxane, however, the extrapolated values of polarizations are probably close to the values for single molecules. The power-factor values for the bromo-acid solutions were higher in the dioxane solutions than in the benzene solutions. The higher association of the acids in the benzene solutions probably influences this difference. In the range of frequencies used in these studies (1,000 cycles to 9,000 kilocycles) for several of the acid solutions, no dielectric dispersion was observed within the experimental accuracy of these observations.

The Influence of Field Strength on the Conductance of Electrolytes—*D. J. Mead, R. M. Fuoss.* At low field strengths, and up to fields of the order of one kilovolt per centimeter, electrolytic solutions obey Ohm's law. In solvents of low dielectric constant, however, dissociation is increased by higher field strengths, leading to an initial increase of conductance proportional to field strength. This behavior is called the Wien effect. The linear increase is followed by a subsequent exponential rise of current with field at very high field strengths, and may be one of the mechanisms involved in the high-voltage breakdown of insulating oils due to the enhanced conductance of the (normally weak) electrolytic impurities in them. An experimental study has been made of the Wien effect in solutions of tetrabutylammonium picrate in diphenyl ether, whose dielectric constant is 3.53. At 10^{-5} normal, this solution has a specific conductance of the order of 10^{-10} mho. Conductances at 60 cycles and 50 degrees centigrade were measured at field strengths up to 20 kilovolts per centimeter. After a small quadratic increase, produced by the dissipation of the ionic atmosphere by the field, the conductance increased linearly, by about 1.5 per cent per kilovolt per centimeter. This agrees with the value calculated by Onsager's theory from the temperature and dielectric constant.

Dielectric Properties of the Rutile Crystalline Modification of Titanium Dioxide—*L. J. Berberich* (*A'30, M'36*), *M. E. Bell.* Most materials have dielectric constants in the range 1–10. Notable among the exceptions is rutile, the crystalline modification of titanium dioxide which is stable at high temperatures. Three samples of this material have been investigated in the form of disks pressed from powdered crystals, then sintered. Curves of dielectric constant against frequency show a rise at very low frequencies, probably attributable to interfacial polarization, with a uniformly high value of approximately 100 extending through the highest radio frequencies, falling off only in the infrared region. With increasing temperature the dielectric constant decreases with an average coefficient of 8.2×10^{-4} per degree in the temperature range of 20 to 120 degrees centigrade. Only a very few of the materials investigated so far show this negative coefficient of dielectric constant. The conductivity of rutile is well represented in the high temperature region by a straight line on a semilog plot against the reciprocal of the absolute temperature. A qualitative explanation of the high dielectric constant and negative temperature coefficient can be made in the light of published work on weakly ionic crystals, assuming that the degree of ionic binding varies with the distance between titanium and oxygen atoms, resulting in a large electric moment being formed for a relatively small movement of the mass points.

Phase Potential at the Boundary Copper–Oil—*A. Gemant.* An effort has been made to determine the degree of resistance of insulating liquids to deterioration by metals, by measurement of the electrochemical potentials at the metal-oil boundary. It is known from theory that the most characteristic feature of electrochemical potential differences is their specific dependence on the concentration in the liquid of the same ions that constitute the metal. The problem, therefore, was to measure the electromotive forces of cells in which the two identical electrodes were immersed in liquids of different metal-ion content. Copper was chosen as a metal, because of its primary importance in electrical machinery. The ion content was produced by dissolving copper oleate in insulating liquids; although solutions of this type are colloidal, they dissociate into ions to a small but finite extent. Data were obtained with cells of the solvent–solution type. According to the thermodynamic equation describing the potentials of such cells, the normal behavior is that the electrode in contact with the more concentrated solution is positive. Data obtained in these tests with solvents such as benzol, xylene, and kerosene indicate that generally the opposite is the case, the normal effect being reversed. By slightly increasing the electric conductivity of the system, the polarity of the electromotive forces changes to the normal one. Data on concentration cells having a solute ratio of 1 to 10 reveal potentials of the expected order of 20 to 30 millivolts.

Corona and Spark-Over—*W. H. Bennett*. Experiments on the electrical discharge from sharp points show that the surface condition of the point cannot be ignored. In many instances, the tip of the discharging point was made sharper by the corona discharge; in others it was dulled. In all cases the tip gradually accumulated a layer of material. Measurements of point discharges in gases other than air have shown that extreme precautions must be taken to eliminate oxygen and other electron attaching gases, in order to obtain discharges free from the pulsating character familiar in air. When such precautions are taken, the discharges are free of pulsations on both negative and positive polarity in hydrogen and helium. The pulsations that occur in carbon monoxide, carbon dioxide, nitrogen, and methane are quite complicated in form in certain ranges, indicating that in these latter gases an explanation different from that of simple electron attachment may be necessary. The pulsations in pure oxygen, ammonia, water vapor in helium, as well as in all unpurified gases are somewhat similar to the pulsations in air.

The Atomphysical Interpretation of Lichtenberg Figures and Their Application to the Study of Gas-Discharge Phenomena—*F. H. Merrill*, *A. von Hippel* (*M'37*). The extremely finely detailed drawing in Lichtenberg figures offers an unusually clear record of the early stages of discharge phenomena. A study has been made of the Lichtenberg discharge in nitrogen at pressures ranging from five millimeters of mercury to 30 atmospheres. The discharge progresses in three stages: the primary figure, spark development, and the discharge of negative surface charges (the "back-figure"). Admixture of carbon tetrachloride and experiments in Freon up to six atmospheres show the decisive influence of electronegative components on the development of the phenomena, and reveal the reasons why these new gases are so effective in suppressing corona discharges. Deviations from Paschen's Law, recently observed by several workers, can be interpreted in terms of the photographic evidence gained.

The Electrical Breakdown Strength of Ionic Crystals as a Function of Temperature—*R. C. Buehl* (*A'36*), *A. von Hippel* (*M'37*). It has been generally believed that the breakdown strength of an insulator is constant in the lower temperature range and decreases rapidly at high temperatures, indicating thermal breakdown. The authors have found that, at least in ionic crystals like potassium bromide, a very steep *increase* of breakdown strength with temperature is recorded in the lower range. This new phenomenon in insulators is apparently analogous to the temperature coefficient of the resistance in metals. It allows us to decide between the different theories of breakdown proposed.

Measurements

Effect of Electrode Materials on the Power Factor of a Cable Oil—*A. V. Astin*. At the National Bureau of Standards an investigation has been undertaken to determine the relative effects of various electrode materials on the insulating properties of some liquid dielectrics. Ten different metals have been used as electrodes, and their effect on a low-loss cable oil (Socony *RD* 1035) observed. The power-factor measurements were made in a conjugate Schering bridge with a stress of about 40 volts per millimeter on the oil. Observations made included 60-cycle and 1,000-cycle power factors and one-minute d-c conductivity. Measurements were made at room temperature, 85 degrees centigrade, two intermediate temperatures, at 85 degrees centigrade after the cell had been maintained at this temperature for a period of 18 hours, and then again on cooling to room temperature. Results of the 60-cycle power-factor tests are summarized as follows (values to be multiplied by 10^{-6}):

Electrode Metal	25 C	85 C	After 18 Hr at 85 C	After Cooling to 25 C
Rhodium plate	8	784	921	10
Silver plate	8.5	914	1,046	18
Gold plate	9	1,124	1,681	32
Nickel plate	10.5	910	1,033	17
Chromium plate	13	1,008	1,502	36
Stainless steel	7	830	1,050	13
Monel metal	7	790	1,470	28
Aluminum	16	1,510	1,610	32
Brass	28	2,000	2,592	115
Anodized aluminum	43	2,700	2,600	72

Results of the d-c tests show practically the same order, since there were only slight differences in the d-c and equivalent 60-cycle conductivities.

The Use of Statistical Methods of Analysis in Insulation Research—*L. Egerton*, *D. A. McLean*. In research studies of impregnated-paper insulation questions are always arising as to the significance to be attached to certain sets of data. This results from the fact that certain properties of the materials can be observed closely enough to be well defined by a limited number of careful measurements while other properties show a decided lack of reproducibility. In order to obtain a good estimate of a property such as life, which varies so widely, an average could be taken of the data obtained on a great many samples. Since life tests are as a rule tedious and expensive, such a solution is seldom practical. This often results in the use of a few observations for estimating the life and necessitates the use of statistical methods of analysis in order to determine with some degree of precision whether or not observed variations in the averages obtained are due to sampling fluctuations or to some assignable cause. However, if prior information regarding its dispersion is available, then statistical methods allow the proper choice of sample size required for a definite desired chance of having an error of not more than a given value in the average. Studies and experiments indicate that statistical methods can be profitably employed for introducing some degree of certainty into a field where the wide fluctuations of data are often confusing.

Decreased Breakdown Strength Caused by Metal and Dielectric Projections in Sphere Gaps—*H. H. Race* (*A'24*, *F'39*). Experiments were performed to determine quantitatively the reductions in spark-over voltages caused by metallic and dielectric projections from the surface of a smooth sphere. Studies were made at 60 cycles per second and with $1^1/_2$x40-microsecond impulses with the projections both positive and negative. For most of the tests, 10-inch spheres were used at a fixed spacing of $5^1/_2$ inches. The projections were cut from thin sheet stock with both the upper and lower edges having the same radius as that of the spheres. The vertical height of the projection was varied from $^1/_8$ inch to 2 inches, that is, the ratio of the projection height to gap spacing varied from 2.3 to 36 per cent. The data obtained emphasized the need for care in eliminating metal or dielectric projections when designing high-voltage apparatus using gaseous dielectrics and indicate how extremely difficult it is in practice to realize the ultimate dielectric strength of the gaseous insulation for given electrode spacings.

Further Progress With a New Optical Method for Studying Electrical Discharges—*S. N. Alexander*. This résumé reports the present status of an investigation whose basic features were reviewed at the 1938 conference (*EE, Jan. 1939, p. 42*). The objective has been the development of a new optical method for recording the details of the predischarge stages of electrical breakdown in gases with eventual extension to transparent liquids and solids. The method uses an adaptation of Toepler's "Schlieren" optical arrangement to reveal the discharge channels through the refractive-index gradients produced by the heat associated with the discharge. These variations in refractive index are used as a shutter-like control for a brilliant light source and the ionization paths appear illuminated against a dark background. Sensitivity sufficient to record the early stages of breakdown in gases was sought and the present equipment approaches the right order of magnitude. An estimate of this sensitivity can be had from the fact that a steady temperature difference of 1.5 degrees centigrade between an electrically heated 0.0002-inch wire and still air can be detected by eye and 3 degrees difference has been photographed. A variety of discharge patterns has been photographed to determine the particular suitabilities and limitations of the system. In addition to recording early stages of formation, this new method has shown several patterns of rather unusual form.

Materials

Effect of Service Aging on Several Brands of 24,000-Volt Paper-Insulated Lead-Covered Cable—*D. E. F. Thomas* (*A'30*), *C. C. Smith* (*A'29*). In these studies, eight sections each of four different kinds of 24-kv 350,000-circular-mil sector-type three-conductor cable were placed in service in two tie lines operating in parallel in the same duct bank; continuous records were kept of cable-loading conditions and duct temperatures. Laboratory tests were made on samples of the new cables cut adjacent to each of the sections placed in service. After approximately three years of service aging, one section of each of the four kinds of cable has been removed for test. Visual examinations of samples cut from each of the four sections disclosed evidence of marked deterioration in only the belted cable impregnated with rosin-free compound. Some deterioration also was found in the shielded cable impregnated with rosin-free compound, but little or none in the shielded and belted cables impregnated with rosin-bearing compound. Measurements of over-all power factor between 20 and 80 degrees centigrade showed an appreciable increase in power factor for the shielded cable impregnated with rosin-free compound and for both of the belted cables at the higher temperatures, but very little change at the lower temperatures. The shielded cable impregnated with rosin-bearing compound showed only a slight increase in over-all power factor. Radial power-factor measurements at 60 degrees centigrade revealed that the rosin-bearing belted cable had a marked increase in power factor throughout the insulation, that the rosin-bearing shielded cable had power-factor increases only near the conductors and shields, and that the rosin-free shielded and belted cables had little or no power-factor increase. Radial hydrophil measurements, made only on the two rosin-free cables showed marked increases near the conductors of the shielded cable, and near the conductors and sheath of the belted cable. Styrenated cross-sectional wafers of all four types of cable showed a slight stretching of the sheaths as a result of service aging. Lead sheath tests disclosed no evidence of sheath deterioration.

Nature of Materials Causing Increase in Power Factor of Liquid Dielectrics Subjected to Corona Discharge—*Joseph Sticher* (*A'30*), *J. D. Piper*. These studies were of two types: First, an analytical approach in which the bombarded material itself was studied; second, an approach in which synthetic materials resembling those found in bombarded hydrocarbons were dissolved in oils. In the analytical studies, which were conducted primarily on decalin, it was found that only the polymerization products had a large effect on power factor, which effect seemed to increase as the degree of polymerization increased. This material appeared to be a highly reactive unsaturated hydrocarbon. Of the synthetic hydrocarbons selected to simulate those formed by corona discharge, however, none brought about an increase in power factor of magnitude even approaching that resulting from similar concentrations of the polymeride formed by corona discharge.

The Dependence of the Conductivity of Dry Paper on Temperature and Voltage—*E. J. Murphy*, *D. A. McLean*. The conductivity of dry paper has been found to increase rapidly with increasing temperature. The relation is not linear when the logarithm of conductivity is plotted against temperature, but becomes linear over long temperature intervals when the logarithm of conductivity is plotted against the reciprocal of the absolute temperature. The conductivity-temperature relation is, therefore, given by the following expression:

$$\gamma = A_1 e^{-B_1/T} + A_2 e^{-B_2/T}$$

where γ is the conductivity, T the absolute temperature, and A_1, A_2, B_1, B_2 are constants. When the logarithm of conductivity is plotted against applied voltage two intersecting straight lines are obtained, indicating that over some ranges of voltage gradient the conductivity increases exponentially with the voltage gradient. The general significance of the results obtained is to indicate that paper behaves more like a material of simple structure than would be expected from the complexity of its structure.

Some Notes on the Application of the Grignard Test to Oil-Impregnated Cable—*R. N. Evans*. By taking advantage of the fact that a Grignard reagent such as n-butyl-magnesium halide yields four times the weight of carbon dioxide per unit volume of hydrocarbon when compared with methyl magnesium halide, a considerable increase in precision may be obtained over some previous methods. In tests made with improved apparatus, the reaction of methyl magnesium iodide in iso-amyl ether at 100 degrees centigrade on type compounds yielded the following results:

1. Ethylbenzoate, benzophenone, n-butanol behaved in a normal manner.

2. Organic acids (benzoic, oxalic, palmitic, acetic, cyclohexane carboxylic, and abietic) gave consistently high results (20 per cent) for the methane evolved and widely scattered yields of reagent added.

3. Peroxides of the benzoyl peroxide type yielded unpredictable results brought about by a deep-seated decomposition of the reagent.

4. Water gave results indicating the lowered reactivity of the second hydrogen in the water molecule.

5. Paper from an atmosphere of 50 per cent humidity indicated that the water on the paper behaved as an alcohol. The excess evolved methane over that equivalent to the independently determined water indicated 1 hydroxyl in 200 was active. A ratio of 1 to 1,000 was obtained for dry paper.

Further experiments at 25 degrees centigrade, brought out that water, acids, and alcohols gave predictable results. It was concluded that a fairly dependable test result representing the alcohol, water, and acid content of an unknown sample may be obtained provided peroxides of certain types were absent. It was further concluded that the measurement of the reagent reacting without evolution of methane would not lend itself to correlation with known groups in the oil sample.

Aging of Cable Insulation Subjected to Elevated Temperatures—a Progress Report—*W. F. Davidson* (*A'14*, *F'26*). The tests reported here are part of a much more comprehensive program to investigate the factors determining the maximum economical loading for paper-insulated high-voltage cables. For this particular phase the problems were:

1. To determine the relative stability of representative present-day commercial cables.

2. To determine the relative deterioration in the temperature range 85–100 degrees centigrade, that is, for temperatures slightly above those recognized in current specifications.

3. To investigate the nature of changes in the insulation resulting from temperature.

Cables used were taken from stock lengths of 2/0 single-conductor, 27-kv (0.297-inch wall) lead-covered cable of each of several makes made in 1938. After discarding 15 or 20 feet, test sections each 2 feet long were cut and immediately sealed with cups pressed from lead which were then "burned" to the sheath. About 15 sections of each cable were then put in each of two specially built ovens and an equal number were placed on storeroom shelves to be kept at room temperature. Automatic regulators with program control maintained the test temperature (85 or 100 degrees centigrade) during 21 hours in each day. During the remaining 3 hours, the temperature cycle is adjusted so that the cable is cooled to about 40 degrees centigrade and immediately reheated. The test program provides for removing samples at intervals of from four to eight months over a total period of three years. Electrical tests are first made on the complete sample which is then cut in two—one part is used for tape-by-tape measurements, while the other provides the basis for chemical tests. Data now are available on three sets of samples representing original conditions, after four months, and after eight months, in the 100-degree oven. The electrical measurements showed considerable differences between the various makes of cable. Some tentative explanations have been advanced to account for these differences, but none has received sufficient confirmation to justify presentation here. As yet it is too early to attempt to draw any conclusions as to the relative deterioration under temperatures of 100 degrees as compared with 85 degrees centigrade, nor is it yet possible to offer any very helpful suggestions as to the nature of the changes that have taken place.

Some Impulse-Voltage-Breakdown Tests on Oil-Treated Paper-Insulated Cables—*C. M. Foust* (*A'22*, *M'31*), *J. A. Scott* (*A'25*, *M'34*). Impulse-breakdown-voltage tests of oil-treated paper-insulated cables have been made over a range of insulation thickness from 0.187 to 0.6 inch. Testing technique has differed somewhat during the period in which the tests were made (1931–38). Early tests employed a 1x10-microsecond wave, and later tests a 1½x40-microsecond wave. In all tests a positive impulse was applied to the conductor, the lead sheath being grounded. Tests on the thinner insulation were made on samples having 10 feet of lead; all others on 16-foot (lead length) samples using standard porcelain oil-filled terminals of usual design. All cable failures were in the leaded portion. An impulse was applied to the cable of a magnitude well below (approximately 50 per cent) expected breakdown. Successive single waves then were applied each exceeding the previous wave by a constant increment until breakdown occurred. Practically all failures occurred on or near wave crest. Breakdown voltages varied over the following ranges:

Thickness of Insulation (Inches)	Impulse Breakdown Voltage (Crest Kv)
0.187	350-400
0.315	448–610
0.500	630–940
0.600	836-1,115

The tests included several grades or densities of papers, and in general the denser papers gave higher breakdown values.

Breakdown in Impregnated-Paper Insulation—the Influence of Paper Density and of Paper Thickness—*J. B. Whitehead* (*A'00, F'12*). Preliminary results of tests on the influence of paper density on the breakdown and stability of impregnated paper reported last year have been confirmed in the complete work. Four grades of paper of different densities, but from the same wood-pulp stock and all of the same thickness were studied in accelerated life tests. The average duration of the test was about four days. With increasing specific gravity of the paper, the dielectric strength of the impregnated sample shows a noticeable decrease. Within the range of the specific gravity of the paper, the decrease in breakdown voltage is 30.5 per cent and the decrease in life 47 per cent. Careful examination and dissection of the specimens revealed that breakdown almost invariably begins in the narrow channels between two successive spirals of the paper tapes, these channels being filled with oil. Corresponding measurements of dielectric constant of the oil, of the paper, and of the impregnated paper, permit computation of the stresses in these oil channels. It was found that these stresses had approximately the same value for all four grades of paper. Thus the decreasing dielectric strength with increasing paper density is caused by the increased dielectric constant of the impregnated paper, as this increase shifts a greater proportion of the total stress to the oil in the oil channels. The values of the stress in the oil channels immediately preceding failure were in the range of 1,300 to 1,500 volts per mil. The changes observed in the conductivity, dielectric constant, and dielectric loss of impregnated paper with increasing paper density were also found to have values greater than could be accounted for by the simple volumetric differences in the two components, oil and paper. (A paper presenting the results of all these tests is scheduled for publication in the 1940 volume of AIEE TRANSACTIONS.) Since the foregoing work, a series of studies on the influence of the thickness of the paper has been completed. Four thicknesses of paper, all of approximately the same specific gravity and all from the same stock, were studied under the same methods as for the studies on paper density. Nine specimens were prepared from each of the four thicknesses, the total wall thickness of the sample being approximately the same for each specimen. All were tested to breakdown, with capacitance and loss measured at regular intervals. A definite drop was noted in dielectric strength with increasing thickness, and also certain variations in the values of capacitance and power factor. Studies are still under way looking toward an explanation of these variations.

Moisture Absorption—Rubber Insulation—Effect on Electrical Characteristics—*E. W. Davis* (*A'15, F'34*). Brief progress report to indicate the continuing pursuit of the investigation initiated in 1937 by the Insulated Power Cable Engineers Association to determine the effects of water absorption on the electrical-insulating characteristics of various rubber insulating compounds. Round-robin programs involving several hundred tests in the laboratories of three different manufacturers conducted during 1938 and again in 1939 have revealed data that are being studied and analyzed. Check-testing now is being carried out by the other member companies of IPCEA. The compounds tested include both the so-called dry types and submarine types. The immediate object of the study is the standardization of test procedure for determining moisture absorption, with the hope of ultimate classification of the various rubber insulating compounds for the different types of service for which each is best suited.

Electrical Properties in Relation to the Chemical Composition of Glass—*C. W. Parmelee, A. E. Badger*. The most important technical glasses are made from mixtures of soda, lime, and silica. The various physical properties, such as viscosity, surface tension, density, thermal expansion, and index of refraction have been determined for most commercial glasses. Among the electrical properties, recent measurements of power factor at 100 to 5,000 kilocycles have been completed for glasses ranging in composition from 0 to 20 per cent lime, 64 to 78 per cent silica, and balance soda. The electrical resistances for the various compositions also have been measured for various temperatures up to 400 degrees centigrade. The results indicate that high-resistance glasses in this range of composition possess low power factors. The lack of correlation between either of these electrical properties and the equilibrium diagram for these compositions confirms the dissimilarity with regard to other physical properties. From systematic studies such as these, it may be possible to develop glasses possessing properties adapted to specialized commercial uses.

Ionization in Thin Air Gaps—*C. L. Dawes* (*A'12, F'35*), *B. I. Small* (*A'38*). At the last two conferences of this committee, one of the authors presented and analyzed the results of an investigation of the electrical characteristics of ionized gas between parallel planes, one of which was a smooth circular metal electrode and the other a smooth glass disk. The investigation has been continued, and the effect of frequency studied. Tests were made on a three-millimeter gap. The impedance of the glass disk is first measured at different values of voltage, frequency, and temperature. The impedance of the glass and the gap in series is then measured, and the impedance of the glass subtracted to obtain the impedance and hence the electrical characteristics of the gap. The gas was dried air, and these tests were made at 30 degrees centigrade and at a pressure of 780 millimeters of mercury, absolute. Rapid changes were found to occur in the characteristics between 40 and 60 cycles. In this region, both curves have a negative slope, go through a point of inflexion, and then a minimum. The characteristics obtained at 25, 30, and 40 cycles appear to be one family of curves, and those obtained at 50, 60, and 70 cycles another family, differing from the first. Rapid changes in power loss and power factor also occur in the 40–60-cycle region in impregnated-paper cables, when ionization exists. Hence there appears to be a close correlation between the gaps studied in the investigation and the ionization that actually takes place in cables. Preparations now are being made to measure the characteristics of very short gaps.

Some Tests on the Power-Factor Stability of Oil-Impregnated Paper—*W. N. Arnquist, C. E. Trautman*. Power-factor measurements on mineral oils having a viscosity of about 100 Saybolt at 100 degrees Fahrenheit have been made. Capacitors were made up with eight layers of 0.5-mil linen capacitor paper separating aluminum foil electrodes, and impregnated, under vacuum, with the oils to be tested. The 60-cycle 30-degree-centigrade power factor of these capacitors was determined as a function of the time that the specimens were exposed to 800 volts per mil, 60 cycles, at 75 degrees centigrade. The effect of the addition of a small percentage of an antioxidant to some of the oils was studied. Separate tests showed that the compositions were not modified by the addition of this compound. With one exception, all the oils tested were derived from Texas coastal distillates. A very marked improvement in power-factor stability resulted from a moderate sulphuric acid treatment of the distillate, with only a relatively slight change in composition; the antioxidant further stabilized the oil. A Texas oil prepared by intensive solvent extraction giving a Waterman aromatic content of less than one per cent was found to be relatively unstable unless the antioxidant was added. In contrast, a moderately treated paraffin oil, with about two per cent aromatics, showed good power-factor stability. For oils derived from a common source, fairly good correlations between the power-factor stability and properties reflecting the initial oil composition are possible.

Some Electrical Properties of Polyvinyl Chloride-Plasticizer Systems—*J. M. Davies, W. F. Busse*. The plasticated polyvinyl chloride being used by the electrical industry as flameproof, oilproof insulation furnishes an unusually interesting system for the scientific study of dielectrics. In the present work the dielectric properties of a series of unstabilized polyvinyl chloride-tricresyl phosphate compounds were studied over a range of temperatures and a range of frequencies. The dielectric constants of these systems may vary from about three at low temperature to nine or ten at high temperatures. The power-factor maxima occur at about the temperatures expected from the dielectric-constant measurements and are shifted to higher temperature by an increase in frequency. An important and entirely unexpected result of this work was the observation that at the temperature of the power-factor maximum the samples all had about the same mechanical flexibility. The upward trend in the power-factor curve at temperatures above the dipole peak probably is due to ionic conductance. This depends on a great many factors, including purity of the polyvinyl chloride and plasticizer, stability and thermal history of the polyvinyl chloride, and presence of stabilizers. The temperature coefficient of the d-c resistance also depends on these factors. In some cases samples which are relatively inferior at high temperatures may be superior at low temperatures. The addition of a stabilizer reduces the d-c conductivity without affecting the loss due to dipole rotation. However, from the practical standpoint, the best compound may not be the one with the best electrical properties, but rather the one that is best from the standpoint of heat loss, flexibility, and toughness.

News

Of Institute and Related Activities

Varied Program Will Feature AIEE 1940 Winter Convention

TECHNICAL sessions of broad current interest, attractive social events, and a particularly stimulating group of inspection trips have been arranged for the 1940 AIEE winter convention, which will be held in New York, N. Y., January 22–26, with headquarters in the Engineering Societies Building. Papers presenting new treatments of existing theories, new designs of electrical apparatus, and the latest in operating practice will be presented in 18 technical sessions, during the mornings and afternoons. Evenings will be occupied by the presentation of the Edison and Hoover Medals, a popular lecture, and the annual smoker and dinner-dance. In addition, eight unusual inspection trips have been planned, and special entertainment for the women guests has been arranged.

MEDAL PRESENTATIONS AND DEMONSTRATION LECTURE

On Wednesday evening, January 24, both the Edison and Hoover Medals will be presented in the engineering auditorium. The Edison Medal was awarded to Philip Torchio "for distinguished contributions to the art of central station engineering and for achievement in the production, distribution, and utilization of electrical energy." As announced in the November 1939 issue, the Hoover Medal "awarded by engineers to a fellow engineer for distinguished public service" will be presented to Gano Dunn.

After the medal presentations a popular lecture on "Atomic Disintegration" will be delivered by Doctor Enrico Fermi, distinguished physicist and Nobel Prize winner in physics for 1938. The lecture will be followed by demonstrations of atomic disintegration by Doctor John R. Dunning of Columbia University.

PRESENTATION OF ALFRED NOBLE PRIZE

Preceding the technical sessions on relays and communication on Tuesday afternoon a general session will be held for the presentation of the Alfred Noble Prize to Claude E. Shannon (A'39) of the Massachusetts Institute of Technology. He was awarded the prize for his paper entitled "A Symbolic Analysis of Relay and Switching Circuits."

ENTERTAINMENT

The smoker, always a popular event, will be held again at the Hotel Commodore, Tuesday evening, January 23. A special cocktail lounge, reserved for AIEE members and guests, will be open at 5:30 p.m. The dinner is scheduled for 6:30 p.m. and the floor show starts at 8:00. There will be a general get-together in the west ballroom at 9:15 p.m. Seating will be at tables for ten on the main floor and at tables for six and eight in the balcony. All tables are reserved. Reservations should be made early with the AIEE smoker committee, 33 West 39th Street, New York, N. Y. Tickets will be $3.50 each, and must be prepaid.

The Grand Ballroom of the Plaza Hotel will be the setting for the annual dinner-dance and buffet supper to be held Thursday evening, January 25. The Plaza, located at Fifth Avenue and 59th Street, overlooking Central Park, is known for its sparkling atmosphere and excellent cuisine. Spacious lounge rooms adjacent to the ballroom will be reserved for the use of members and their guests during the dance.

Outdoor parking facilities are excellent in the neighborhood and indoor parking will be available at a nominal fee. For those who wish to stay overnight or to dress at the hotel arrangements have been made for a special rate on rooms. For room reservations write or telephone the hotel and mention the AIEE.

George Ellner and his orchestra will again provide music for both the dinner and dance. As in previous years, encores will be limited in order to provide a large number of dances during the evening.

The program for the evening is:

7:00 p.m.	Dinner
9:30 p.m. to 2:00 a.m.	Dancing
Midnight to 2:00 a.m.	Buffet supper

The prices for tickets are:

Dinner and dance	$5.00 per person
Dinner, dance, and buffet supper.	6.50 per person
Dance and buffet supper.........	3.00 per person

Dinner reservation requests should be sent to AIEE dinner-dance committee, 33 West 39th Street, New York, N. Y., checks being made payable to "Special Account, AIEE." All such requests should include names of guests and desired seating arrangements, taking into account the fact that tables seat eight or ten persons. The committee requests that tickets be purchased as early as possible to allow time to work out seating arrangements.

TECHNICAL CONFERENCES

Nine conferences have been tentatively arranged, on the following subjects: electric welding, feedback amplifiers, networks, sound, test code for synchronous machines, transportation, increasing use of electronic devices, standards, and definitions. The schedule for these conferences and as much information as is available is given in the technical program.

The conference on sound is sponsored by

Summarized Schedule of Principal Events

(See separate program for women's entertainment)

Monday, January 22

9:00 a.m.	Registration
10:00 a.m.	Electric welding
11:30 a.m.	Conference on electrical welding
10:00 a.m.	Basic sciences and automatic stations Conference on feedback amplifiers
2:00 p.m.	Lightning protection Communication I Conference on networks

Tuesday, January 23

9:30 a.m.	Circuit breakers Communication II Industrial power applications
2:00 p.m.	General session
2:15 p.m.	Relays Conference on sound
6:30 p.m.	Smoker, Commodore Hotel

Wednesday, January 24

9:30 p.m.	Power generation Transportation I Electronics Conference on test code for synchronous machines
2:00 p.m.	Production and application of light Transportation II
3:45 p.m.	Conference on transportation
2:00 p.m.	Conference on increasing use of electronic devices
8:00 p.m.	Edison and Hoover medal presentations; demonstration lecture on "Atomic Disintegration"

Thursday, January 25

9:30 a.m.	Power transmission Instruments and measurements Electrical machinery I
2:00 p.m.	Insulation co-ordination Electrical machinery II Conference on standards Conference on definitions
7:00 p.m.	Dinner-dance, Plaza Hotel

Friday, January 26

All day	Inspection trips

Saturday, January 27

Post-convention trip to Jamestown, Va., and historic Williamsburg to visit the restoration. Further information at the convention registration desk

Technical Program

Monday, January 22

10:00 a.m. Electric Welding

40-11. Power-Factor Correction of Resistance-Welding Machines by Series Capacitors. **L. G. Levoy, Jr.**, General Electric Company

40-55. The Measurement of Spot-Welding Current. **W. F. Hess, R. A. Wyant**, and **Albert Muller**, Rensselaer Polytechnic Institute

40-56. Resistance of the Spot Weld. **Ladislav Ciganek**, Cechy-Morava

40-57. Power Supply for Resistance-Welding Machines—II, Resistance-Welder Installations. **Subcommittee on Power Supply for Welding Operations, AIEE**

11:30 a.m. Conference on Electric Welding

40-58-ACO.* Power Supply for Resistance-Welding Machines—I, Guide to Good Electrical Performance of Resistance-Welding Machines. **Subcommittee on Power Supply for Welding Operations, AIEE**

10:00 a.m. Basic Sciences and Automatic Stations

40-5. Analysis of Transient Voltages in Networks. **P. L. Bellaschi** and **A. J. Palermo**, Westinghouse Electric and Manufacturing Company

40-2. Transient Analysis of Symmetrical Networks by the Method of Symmetrical Components. **L. A. Pipes**, Harvard University

40-21. Generalized Bridge Network for Dielectric Measurements. **J. C. Balsbaugh, A. H. Howell**, and **J. V. Dotson**, Massachusetts Institute of Technology

40-26. Synchronizing Transients and Synchronizers for Large Machines. **R. D. Evans, F. H. Gulliksen**, and **C. B. Myhre**, Westinghouse Electric and Manufacturing Company

10:00 a.m. Conference on Feedback Amplifiers

2:00 p.m. Lightning Protection

40-22. Lightning Protection of Wood-Pole Lines. **H. K. Sels** and **A. W. Gothberg**, Public Service Electric and Gas Company

40-59. Lightning Currents in Arresters at Stations. **I. W. Gross**, American Gas and Electric Company, and **W. A. McMorris**, General Electric Company

40-60. Lightning and Lightning Protection on Distribution Systems. **R. C. Bergvall** and **Edward Beck**, Westinghouse Electric and Manufacturing Company

40-61. Enclosed Spark Gaps. **W. E. Berkey**, Westinghouse Electric and Manufacturing Company

40-62. Station-Type Lightning-Arrester Performance Characteristics. **Lightning Arrester Subcommittee, Committee on Protective Devices, AIEE**

2:00 p.m. Communication I: Use of Radio for Airplane Navigation and Weather Forecasting

40-43. The Development of the Civil Aeronautics Authority Instrument Landing System at Indianapolis. **W. E. Jackson**, Civil Aeronautics Authority, **Andrew Alford** and **P. F. Byrne**, International Telephone Development Company, and **H. B. Fischer**, Bell Telephone Laboratories, Inc.

Photo-offset copies of authors' manuscripts, except addresses, may be obtained in advance of the convention by writing to the AIEE Order Department, 33 West 39th Street, New York, N. Y. Only numbered papers will be available in advance copy form. If ordered by mail, price 10¢ per copy; if purchased at Institute headquarters or at the convention, 5¢ per copy. Mail orders (particularly from out-of-town members) are advisable, inasmuch as an adequate supply of each paper at the meeting cannot be assured. Coupon books in $1.00 and $5.00 denominations are available for those who wish to avoid remittance by check or otherwise. Most of the papers ultimately will be published in ELECTRICAL ENGINEERING or the TRANSACTIONS.

40-44. The CAA-MIT Instrument Landing System. **E. L. Bowles, W. L. Barrow, W. M. Hall, F. D. Lewis**, and **D. E. Kerr**, Massachusetts Institute of Technology

40-45. Ultrahigh-Frequency Loop Antennas. **Andrew Alford** and **A. G. Kandoian**, International Telephone Development Company

40-47. Upper-Air Weather Soundings by Radio. **Harry Diamond, W. S. Hinman, Jr., F. W. Dunmore**, and **E. G. Lapham**, National Bureau of Standards

2:00 p.m. Conference on Networks

Tuesday, January 23

9:30 a.m. Circuit Breakers

40-19. The Cross-Air-Blast Circuit Breaker. **D. C. Prince** and **W. K. Rankin**, General Electric Company, and **J. A. Henley**, Metropolitan Vickers Company Ltd.

40-63. Design and Construction of High-Capacity Air-Blast Circuit Breakers. **H. E. Strang** and **A. C. Boisseau**, General Electric Company

40-64. A New 15-Kv Pneumatic Circuit Interrupter. **L. R. Ludwig, H. L. Rawlins**, and **B. P. Baker**, Westinghouse Electric and Manufacturing Company.

40-65. Magnetic Deion Air Breaker for 2,500–5,000 Volts. **L. R. Ludwig** and **R. H. Nau**, Westinghouse Electric and Manufacturing Company

40-66. Circuit Interruption by Air Blast. **W. S. Edsall** and **S. R. Stubbs**, Allis-Chalmers Manufacturing Company

9:30 a.m. Communication II

40-49. Co-ordination of Power and Communication Circuits for Low-Frequency Induction. **J. O'R. Coleman**, Edison Electric Institute, and **H. M. Trueblood**, Bell Telephone Laboratories, Inc.

40-50. Control of Inductive Interference to Telegraph Systems. **J. W. Milnor**, Western Union Telegraph Company

40-51. High-Speed Voice-Frequency Carrier Telegraph System. **F. B. Bramhall**, The Western Union Telegraph Company

40-20. Compressed Powdered Molybdenum Permalloy for High-Quality Inductance Coils. **V. E. Legg** and **F. J. Given**, Bell Telephone Laboratories, Inc.

40-52. Calculation and Design of Resistance-Coupled Amplifiers Using Pentode Tubes. **F. E. Terman, W. R. Hewlett, C. W. Palmer** and **Wen-Yuan Pan**, Stanford University

40-53. Contact Phenomena in Telephone Switching Circuits. **A. M. Curtis**, Bell Telephone Laboratories, Inc.

9:30 a.m. Industrial Power Applications

40-7. Dynamoelectric Amplifier for Power Control. **E. F. W. Alexanderson, M. A. Edwards**, and **K. K. Bowman**, General Electric Company

40-10. The Design Characteristics of Amplidyne Generators. **Alec Fisher**, General Electric Company

40-23. Industrial Applications of Amplidyne Generators. **D. R. Shoults, M. A. Edwards**, and **F. E. Crever**, General Electric Company

40-54. Characteristics and Power Requirements of Spinning Frames, II. **E. A. Untersee**, General Electric Company

2:00 p.m. General Session

Presentation of Alfred Noble Prize to Claude E. Shannon, Massachusetts Institute of Technology

2:15 p.m. Relays

40-67. Over-Current Performance of Bushing-Type Current Transformers. **C. A. Woods, Jr.**, and **S. A. Bottonari**, Westinghouse Electric and Manufacturing Company

40-68. A Proposed Method for the Determination of Current-Transformer Errors. **G. Camilli** and **R. L. Ten Broeck**, General Electric Company

40-69. Analysis of Bushing-Current-Transformer Performance. **J. P. Gebelein**, Consumers Power Company, and **J. A. Elzi**, Commonwealth and Southern Corporation

40-70. Transient Characteristics of Current Transformers. **A. T. Sinks**, General Electric Company

40-71. Current Transformers and Relays for High-Speed Differential Protection, With Particular Reference to Offset Transient Currents. **E. C. Wentz** and **W. K. Sonnemann**, Westinghouse Electric and Manufacturing Company

2:15 p.m. Conference on Sound

CP.† New Information on Sound Levels Existing in Various Locations. **D. F. Seacord**, Bell Telephone Laboratories, Inc.

CP.† Progress in Sound-Level Meter Standards—Calibration Methods and Tolerances. **J. M. Barstow**, Bell Telephone Laboratories, Inc.

CP.† Progress in Vibration Measurements—Shall a Test Code on This Subject Be Developed? **C. D. Greentree**, General Electric Company

CP.† Experiences in Sound Measurements. **E. J. Abbott**, Physicists Research Company

40-13. Harmonic Theory of Noise in Induction Motors. **W. J. Morrill** General Electric Company

Wednesday, January 24

9:30 a.m. Power Generation

40-30. The Design and Operation of a Metropolitan Electrical System From the Viewpoint of Possible Major Shutdowns. **S. M. Dean**, The Detroit Edison Company

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* ACO: Advance copies only available; not intended for publication in TRANSACTIONS.

† CP: Conference paper; no advance copies available; not intended for publication in TRANSACTIONS.

Technical Program (Continued)

40-31. Restoration of Service From Large Metropolitan System After Complete Shutdown. **H. A. Dryar** and **Raymond Bailey**, Philadelphia Electric Company

40-32. Restoration of Service on a Metropolitan Power System. **W. C. Bryson** and **A. P. Hayward**, Duquesne Light Company

40-33. Provisions for Re-energizing the Electric System of the Consolidated Edison Company of New York, Inc. **G. R. Milne** and **H. C. Otten**, Consolidated Edison Company of New York, Inc.

40-6. Report on Power Generation. **AIEE Committee on Power Generation, 1938–1939** (*EE, Jan. '40 p. 12–22.*)

9:30 a.m. Transportation I

40-4. Railway Power Supply. **Philip Torchio**, retired, Consolidated Edison Company of New York, Inc.

40-27. Power Supply for Railroad Electrification and Fundamentals of Power Contracts. **E. R. Hill**, Gibbs and Hill, Inc.

40-14. The Application of Traction Motors. **F. E. Wynne** and **G. M. Woods**, Westinghouse Electric and Manufacturing Company

40-16. Network Coupling by Means of Static Electronic Frequency Changers. **O. K. Marti**, Allis-Chalmers Manufacturing Company

9:30 a.m. Electronics

40-74. Excitron Mercury-Arc Rectifier. **O. K. Marti**, Allis-Chalmers Manufacturing Company

40-18. A New Electronic Multiplier for Power Frequencies. **W. P. Overbeck**, Massachusetts Institute of Technology

40-72. Condensation of Mercury in Mercury-Arc Tubes. **Joseph Slepian** and **W. M. Brubaker**, Westinghouse Electric and Manufacturing Company

40-73. Phase Occurrence of Arc-Backs in High-Current Mercury-Arc Rectifiers. **W. E. Pakala** and **W. B. Batten**, Westinghouse Electric and Manufacturing Company

40-75. A New Postgraduate Course in Industry in High-Frequency Engineering. **A. R. Stevenson, Jr.**, and **Simon Ramo**, General Electric Company

9:30 a.m. Conference on Test Code for Synchronous Machines

2:00 p.m. Production and Application of Light

40-1. Report on Progress in the Production and Application of Light—Demonstration lecture. **A. L. Powell**, General Electric Company (*EE, Dec. '39, p. 497–508*)

Address: Lighting the New York World's Fair. **R. C. Engelken**, New York World's Fair Corporation

Address: Lighting of the North Beach Airport. **Major Haslett**, aviation consultant at the New York Municipal Airport

2:00 p.m. Transportation II

40-15. Unsolved Problems of Electrical Engineering in the Field of Transportation. **J. A. Noertker**, Cincinnati Street Railway Company

40-28. Electric Braking for Railroad and Urban Transit Equipment. **F. H. Craton** and **F. M. Turner**, General Electric Company

40-24. Electric Power for Airplanes. **W. J. Clardy**, Westinghouse Electric and Manufacturing Company

3:45 p.m. Conference on Transportation

40-29-ACO.* Trends in Railroad Motive Power. **Sidney Withington**, New York, New Haven, and Hartford Railroad Company

2:00 p.m. Conference on Increasing the Use of Electronic Devices

Thursday, January 25

9:30 a.m. Power Transmission

40-17. Engineering Features of the 230-Kv Boulder-Chino Transmission Line of the Southern California Edison Company, Ltd. **A. A. Kroneberg**, Southern California Edison Company, Ltd., and **E. M. Hunter**, General Electric Company

40-25. What Wood May Add to Primary Insulation for Withstanding Lightning. **J. T. Lusignan** and **C. J. Miller**, Ohio Brass Company

40-9. Surge Characteristics of a Buried Bare Wire. **E. D. Sunde**, Bell Telephone Laboratories, Inc.

40-8. Some Impulse-Voltage Breakdown Tests on Oil-Treated Paper-Insulated Cables. **C. M. Foust** and **J. A. Scott**, General Electric Company

40-34. Impulse Strength of Cable Insulation. **E. W. Davis** and **W. N. Eddy**, Simplex Wire and Cable Company

9:30 a.m. Instruments and Measurements

40-39. The Speedomax Power-Level Recorder. **W. R. Clark**, Leeds and Northrup Company

40-40. The Accuracy of Watt-Hour Meters on Intermittent Loads. **M. A. Faucett**, **C. A. Keener**, and **M. S. Helm**, University of Illinois

40-41. A Primary Rotating Standard for the Measurement of Kilowatt Hours. **J. H. Goss** and **A. Hansen, Jr.**, General Electric Company

40-42. Watt-Hour-Meter Performance With Power Rectifiers. **C. T. Weller**, **H. E. Trekell**, and **F. O. Stebbins**, General Electric Company

40-48. The Vector-Response Indicator. **B. D. Loughlin**, Hazeltine Service Corporation

9:30 a.m. Electrical Machinery I

40-77. Water Solution in High-Voltage Dielectric Liquids. **F. M. Clark**, General Electric Company

40-78. Determination of Short-Circuit Torques in Turbine Generators by Test. **E. C. Whitney** and **H. E. Criner**, Westinghouse Electric and Manufacturing Company

2:00 p.m. Insulation Co-ordination

40-83. Basic Impulse Insulation Levels. **Philip Sporn**, American Gas and Electric Company, and **C. A. Powel**, Westinghouse Electric and Manufacturing Company

40-35. The Co-ordination of Electrical Equipment With Basic Insulation Levels. **J. H. Foote** and **J. R. North**, The Commonwealth and Southern Corporation

40-36. Rationalization of System Insulation III, Margins Between Basic Insulation Levels and Protectable Levels. **Philip Sporn** and **I. W. Gross**, American Gas and Electric Company

40-37. Proposed Standards for Outdoor Bushings. **AIEE Joint Committee on Bushings.**

40-38. Recommendations for High-Voltage Testing. **Subcommittee on Correlation of Laboratory Data of EEI-NEMA Joint Committee on Insulation Co-ordination**

2:00 p.m. Electrical Machinery II

40-79. Heating of a D-C Armature. **C. J. Fechheimer**, Milwaukee School of Engineering

40-80. Theory of Hysteresis Motor Torque. **B. R. Teare, Jr.**, Carnegie Institute of Technology

40-12. Induction Motor Characteristics at High Slip. **T. H. Morgan**, Worcester Polytechnic Institute, **W. E. Brown**, Colt's Patent Fire Arms Manufacturing Company, and **A J. Schumer**, Fischbach and Moore, Inc.

40-3. Starting Performance of Salient-Pole Synchronous Motors. **M. M. Liwschitz**, Westinghouse Electric and Manufacturing Company

40-46. Electric Couplings. **M. R. Lory**, **L. A. Kilgore**, and **R. A. Baudry**, Westinghouse Electric and Manufacturing Company

2:00 p.m. Conference on Standards

2:00 p.m. Conference on Definitions

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the subcommittee on sound of the standards committee to review recent developments in the field of sound and vibration measurement. Speakers will present new information on sound levels existing in various locations; on progress in sound level meter standards, particularly calibration methods and tolerances; and on recent experiences in sound measurement in various fields. It is also planned to renew discussion of vibration measurements, which are more and more coming to be made by means of sound-level meters using suitable vibration pick-up devices.

This annual conference serves as a means of bringing forward new proposals for sound measurement or noise reduction, and acquainting Institute members with progress in the sound-measurement art.

Inspection Trips

The inspection trips committee is arranging a program of inspection trips throughout the week and on Friday, which is to be devoted entirely to this activity. The following are among those scheduled:

1. Train-dispatching operations and inspection of latest car-lighting applications at Grand Central Terminal.

2. Inspection of NBC television broadcasting studios at Radio City, transmission apparatus at the Empire State Building, and television receivers.

3. Trip to General Cable Corporation plant at Bayonne, N. J.

4. Trip to Westinghouse Lamp Works, Meter Works, and Elevator Factories; luncheon at the Lamp Works.

5. Inspection of Associated Press building, equipment and operations.

6. American Telephone and Telegraph Company traffic-control demonstration. Attendance limited to members only.

7. Inspection of New York Telephone Company cross-bar central office.

8. Trip to New York Municipal Airport, North Beach; sightseeing flight over New York City in modern transport planes; and demonstration of field lighting.

In addition to the trips, tickets to several broadcasts will be available to members attending the convention. Arrangements may also be made for a post-convention trip

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to Jamestown and historic Williamsburg, Va., to see the restoration. Further details will be available at the convention registration desk. Among the preceding list of inspection trips the following are believed to be of more than usual interest:

Traffic Control Demonstration. In the New York headquarters building of the American Telephone and Telegraph Company's long lines department is a group of men and women known as the traffic control bureau. There are similar groups in Cleveland and Chicago. Together they direct and co-ordinate the movement of telephone traffic over more than two and a half million miles of long-distance lines.

Every day—almost every hour—brings sudden sharp variations from the average flow of telephone calls. Hurricanes and floods, conventions and World Series games—these and other events make necessary quick and often extensive rearrangements of long-distance facilities. Calls must be detoured around line breaks. Additional circuits are urgently required. Other emergency adjustments may have to be made.

To illustrate the traffic control bureau's important part in keeping calls moving under such circumstances, the work of the bureau has been dramatized for demonstration purposes. In a fast-moving 50-minute presentation, employees in the New York bureau re-enact an actual case involving a major cable break. The action starts with the first report of trouble. Telephone and teletypewriter flash information between the bureau and distant offices. Advice, reports, suggestions speed from New York to key points in a dozen directions. Discussions take place over conference hook-ups. A growing number of circuits are arranged to by-pass the break. Finally the display board, which records the minute-by-minute condition of each circuit, resumes its normal appearance. Service is going along at its usual pace.

Some Winter-Convention Attractions

(See Facing Page)

1, 2. An inspection trip to the newly opened New York Municipal Airport will include a 75-mile air trip for a limited number, a tour of the landplane administration building and three hangars (1) and an inspection of the glass enclosed control tower atop the administration building (2)

3, 4, 5. Radio City, a perennial favorite among winter conventioners since the huge Music Hall theater was opened there several years ago, now has its tallest structure—the 70-story RCA building—floodlighted at night (5). In addition to the usual attractions, there will be an inspection trip to the television studios of the National Broadcasting Company, which will include a tour of the NBC building, a modern television studio, and control room (4). There will also be an opportunity to see the television transmitters and antenna (3) at the pinnacle of the Empire State Building

6, 7. Inspections of communication facilities will include: traffic-control office of the American Telephone and Telegraph Company (6) where the work of the traffic-control bureau will be demonstrated; and a cross-bar central office (7)

8. The gleaming towers of New York's financial district from the air

Photos courtesy of: (1) Transcontinental and Western Air, Inc.—William T. Hoff; (2) *Aviation*; (3, 4) National Broadcasting Company; (5) Westinghouse; (6, 7) American Telephone and Telegraph Company; (8) American Airlines

On January 26 the demonstration will be given twice for members of the Institute, at 10:00 and 11:15 a.m., in the long-distance building, 32 Sixth Avenue. Admission will be by ticket only, and the number of tickets is limited. Application for reservations should be made at the inspection trips desk early during the convention.

NBC Television Studio Facilities at Radio City. Members in groups of approximately 20 will be given an opportunity to inspect the NBC building, where they will see a modern television studio with latest lighting equipment, cameras and production facilities, control room and control equipment used in the production of live-talent performances.

Inspection will include the projection studio which is equipped to transmit both 35- and 16-millimeter motion pictures. Installed in this pioneer television production plant are the very latest types of RCA television equipment developed in actual practice over a period of three years of practical operation. In the live-talent studio, the camera will be in operation, so that members who take this trip will be able to see their companions appear on the monitor through the television system.

Those interested in seeing the NBC sound and vision transmitters will be afforded an opportunity to go to the Empire State Building and there inspect these modern ultrashort-wave television transmitters.

Tickets, assigning a specific time for the arrival of each group at Radio City, will be distributed to members requesting them.

New York Municipal Airport. A series of five scenic flights that will permit members attending the convention to view New York City from the air will be operated from New York's new $50,000,000 LaGuardia Field on Friday, January 26. Arrangements have been completed with United Air Lines enabling 105 people to make 75-mile trips around the five boroughs of the skyscraper city in 21-passenger transports.

Accompanying the air trip will be a tour of the huge landplane administration building and the three hangars now being shared by four lines, American, United, TWA, and Canadian Colonial. Three other hangars are nearing completion and a fourth is projected. Similar in size, each will be larger than Madison Square Garden.

One of the finest air terminals in the world, LaGuardia Field has combined facilities within its 558-acre space for both a landplane and seaplane base and ultramodern facilities for passenger handling. The administration building, more than four stories in height, has separate levels for incoming and outbound passengers and promenade decks for sightseers. In the building are three restaurants, a coffee shop, barber shop, newsstand, and flower shop. Above the passenger levels are operating offices for some of the airlines—nerve centers for plane control via radiotelephone and teletype. The highest part of the building is the glass-enclosed control tower from which takeoffs, landings, and approaches are guided. On this tower, which will be shown on the guided tour, is a revolving beacon said to be the most powerful in the world. The lighting of the airport is to be described at one of the sessions by Major Haslett, aviation consultant at the airport.

Women's Program

In addition to the medal presentations on Wednesday evening and the dinner-dance on Thursday evening, women guests will be interested in the following events arranged by the women's entertainment committee, under the chairmanship of Mrs. G. S. Rose.

Monday, January 22

9:00 a.m.–4:00 p.m. Registration

Tuesday, January 23

10:00 a.m. Bus trip around both upper and lower New York, returning to Engineering Societies' Building at 1:30 p.m. Special coaches with glass roof and lecturer. Special rate $1.50. Please register on Monday. Men welcome.

3:00 p.m. Radio City. Tea in the Rainbow Room and a trip to the Tower, courtesy of Westinghouse

7:30 p.m. "Consolidated Edison" broadcast

9:00 p.m. "We the People" broadcast

Wednesday, January 24

Annual luncheon and bridge, Ambassador Hotel

Thursday, January 25

Various trips to museums, art galleries, and other points of interest.

Hotels and Registration

Reservations for hotel accommodations should be made by writing directly to the hotel of your preference. Members east of the Mississippi who receive the mailed announcement of the winter convention should fill in and post promptly the mail registration card. This will permit badges to be made ready in advance of arrival and avoid congestion at the registration desk. There will be a registration fee of $2.00 for nonmembers, except Enrolled Students of the Institute and the immediate families of members.

Winter Convention Committee

The personnel of the 1940 winter convention committee is as follows: A. F. Dixon, chairman; J. W. Barker, T. F. Barton, G. E. Dean, E. E. Dorting, L. C. Miller, A. G. Oehler, J. H. Pilkington, C. S. Purnell, George Sutherland, and W. W. Truran. The chairmen of the subcommittees completing the arrangements are: T. S. Bacon, dinner-dance; D. W. Taylor, smoker; R. F. Brower, inspection trips; and Mrs. G. S. Rose, women's entertainment.

Committee to Nominate AIEE Officers for 1940–41

In accordance with the Institute's bylaws, the national nominating committee of the AIEE will meet during the winter convention to be held in New York, N. Y., January 22–26, 1940, for the purpose of nominating national officers to be voted upon by the membership in the spring of 1940. Members of this year's national nominating committee are as follows:

Representing the Board of Directors

C. R. Beardsley, Consolidated Edison Company of New York, Inc., New York, N. Y.

Chester L. Dawes, Harvard University, Cambridge, Mass.

Mark Eldredge, Memphis Light, Gas, and Water Division, Memphis, Tenn.

A. H. Lovell, University of Michigan, Ann Arbor.

C. A. Powel, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Representing the Ten Geographical Districts

1. W. B. Hall, Rhode Island State College, Kingston, R. I.
2. I. Melville Stein, Leeds and Northrup Company, Philadelphia, Pa.
3. George Sutherland, Consolidated Edison Company of New York, Inc., New York, N. Y.
4. J. Coleman Jones, Florida Power and Light Company, Miami.
5. T. G. LeClair, Commonwealth Edison Company, Chicago, Ill.
6. A. L. Turner, Northwestern Bell Telephone Company, Omaha, Nebr.
7. A. S. Langsdorf, Washington University, St. Louis, Mo.
8. Fred Garrison, General Electric Company, Los Angeles, Calif.
9. Henry L. Vincent, Westinghouse Electric Supply Company, Spokane, Wash.
10. J. M. Thomson, Ferranti Electric, Ltd., Toronto, Ont.

Alternates for board representatives:

T. F. Barton, General Electric Company, New York, N. Y.

H. S. Osborne, American Telephone and Telegraph Company, New York, N. Y.

Provisions of the AIEE constitution and bylaws relating to nominations were given in Electrical Engineering for November 1939, page 484. President Farmer's message, on page 449 of the same issue, outlined the election machinery, and made suggestions for broader participation in nominations.

In addition to those to be designated by the national nominating committee, nominations also may be made independently, by petition of 25 or more members sent to the national secretary at Institute headquarters, not later than March 25, to be placed before the nominating committee for inclusion in the ballot of such candidates as are eligible. Petitions for the nomination of vice-president may be signed only by members within the District concerned.

Future AIEE Meetings

Winter Convention
New York, N. Y., January 22–26, 1940

Summer Convention
Swampscott, Mass., June 24–28, 1940

Pacific Coast Convention
Los Angeles, Calif., August 26–30, 1940

Charles LeGeyt Fortescue Fellowship Established

A fellowship for graduate study, sponsored by the AIEE, has been established as a memorial to Charles LeGeyt Fortescue (A'03, F'21) in recognition of his valuable contributions to the electric-power industry. A trust fund of $25,000 has been set up for this purpose by the Westinghouse Electric and Manufacturing Company, with which Doctor Fortescue was associated throughout his professional career. The income, which will be administered by a committee of the AIEE, will be used to provide fellowships of $500 or more to candidates selected annually by the committee.

Holders of the fellowships will be expected to pursue their studies at accredited engineering schools and to engage in research problems meeting the approval of the committee. Any student of electrical engineering who has received a bachelor's degree before the fellowship becomes active is eligible for the awards. Candidates must make application in due form to the secretary of the fellowship committee before February 15. Application forms are available at accredited colleges or may be obtained from the secretary at AIEE headquarters, 33 West 39th Street, New York, N. Y. Awards will be made not later than April 1. Fellowships will not be awarded to those who hold or may hold other fellowships that carry stipends greater than the tuition of the institution at which graduate study will be undertaken.

Charles LeGeyt Fortescue, in whose honor the awards have been founded, was born November 7, 1876, at York Factory, Manitoba, Can. He was the first student graduated as an electrical engineer from Queen's University, which later awarded him the degree of doctor of laws. Following graduation in 1898 he joined the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., where he spent his entire professional life. He died December 4, 1936. A prolific inventor, holder of some 185 patents, he is probably best known for his system of symmetrical coordinates used in the solution of unbalanced polyphase circuits, for which he was awarded the Elliott Cresson Medal of the Franklin Institute. His analysis of the fundamentals of transmission circuit stability and his theories of lightning behavior and derived principles of lightning protection are also conspicuous as lasting achievements, while among his contributions to the problems of his time are his rationalization of transformer design, studies of high-voltage measurements culminating in the adoption of the standard sphere spark gap, and fundamental work on porcelain insulator surface shapes involving the "faradoid" principle.

1939 Noble Prize Awarded to Institute Member

The Alfred Noble prize for 1939 has been awarded to C. E. Shannon (A'39) assistant in mathematics, Massachusetts Institute of Technology, Cambridge, for his paper "A Symbolic Analysis of Relay and Switching Circuits." The paper, an abstract of a thesis for master's degree, prepared while the author was a research assistant at MIT and a student member of the Institute, was presented at the AIEE summer convention, Washington, D. C., June 20–24, 1938, and published in the 1938 Transactions, pages 713–23. A biographical sketch of Mr. Shannon appears in the "Personal Items" section of this issue, page 48. Formal presentation of the award will be made at the AIEE winter convention to be held in New York, N. Y., January 22–26.

Instituted in 1929 in honor of Alfred Noble, past-president of the American Society of Civil Engineers and of the Western Society of Engineers, the prize has been presented seven times, the first award having been made in 1931. It consists of a $500 cash award and a certificate. Mr. Shannon is the fourth AIEE member to receive it, the others being F. M. Starr (A'30, M'37) 1932; Abe Tilles (A'30, M'36) 1936; and G. M. L. Sommerman (A'31, M'37) 1937. The recipient is selected by a committee of five, representing the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, the AIEE, and the Western Society of Engineers. The award is made to a member of one of those societies for a technical paper of particular merit accepted by the publication committee of any of the societies for publication in whole or in abstract in any of their respective publications, provided that the author is not over 30 years of age at the time the paper is accepted in practically its final form. The award is now made for papers presented during the 12 months preceding June 1 of each year.

AIEE Executive Committee Meets at Headquarters

A meeting of the executive committee of the AIEE was held at Institute headquarters, New York, N. Y., on December 11, 1939, in place of the regular meeting of the board of directors.

Present: President F. Malcolm Farmer, chairman, W. H. Harrison, K. B. McEachron, H. S. Osborne, John C. Parker, W. I. Slichter, members of the committee; National Secretary H. H. Henline.

Executive committee action on applications as of November 21, 1939, was reported and approved, as follows: 3 applicants transferred to the grade of Fellow; 14 applicants transferred and 4 elected to the grade of Member; 23 applicants elected to the grade of Associate; 572 Students enrolled.

A report was presented and approved of actions taken by the board of examiners at its meeting held on November 16, 1939.

Disbursements in November, amounting to $21,787.79, were reported by the chairman of the finance committee and approved.

The executive committee granted a request of the technical program committee for an extension of the authority already given it to hold a joint session with Section M (Engineering) of the American Association for the Advancement of Science at one of the Institute's conventions to include authority to hold a joint session with American Engineering Council.

Upon recommendation of the Sections committee, authorization was given for the organization of a Charleston, W. Va., Section of the Institute.

Report was made of the completion of the duties of the special committee appointed to collaborate with the Westinghouse Electric and Manufacturing Company in working out the details for the establishment of a graduate fellowship as a memorial to the late Charles LeGeyt Fortescue, to be known as the Charles LeGeyt Fortescue Fellowship, the funds for the purpose being donated by the Westinghouse Company and the fellowships to be awarded by a committee of the AIEE. The trust agreement between the Westinghouse company and the Institute had been signed, and bylaws of the AIEE committee that will award the fellowships had been adopted. The special committee, therefore, was discharged, with an expression of appreciation of its services.

Upon request of the committee on engineering schools of the Engineers' Council for Professional Development, approval was given for the appointment of the following AIEE representatives on delegatory committees of ECPD, engaged in the ECPD program for accrediting engineering schools: T. H. Morgan and H. B. Richmond, Region I; C. H. Willis, Region II; A. C. Lanier, Region V; F. O. McMillan, Region VII.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

Eta Kappa Nu Awards Announced for 1939

L. A. Meacham, Bell Telephone Laboratories, Inc., New York, N. Y., has been named by Eta Kappa Nu, honorary electrical engineering society, to receive its Recognition of Outstanding Young Electrical Engineers for 1939. Mr. Meacham was chosen from over 40 candidates nominated from every section of the country by heads of college electrical-engineering departments, personnel directors in the electrical industry, and Sections of the AIEE. He is the fourth man to receive this honor. Two honorable-mention awards have also been announced for 1939, to be given to C. K. Gieringer (A'35), chief engineer, Liebel - Flarsheim Company, Cincinnati, Ohio, and J. E. Hobson (A'36), Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Biographical sketches of the honorable-mention winners appear in the "Personal Items" section of this issue, page 48.

The awards were made by a committee of prominent engineers: Chairman H. S. Rogers, president, Polytechnic Institute of Brooklyn; Morris Buck, engineering editor, *Transit Journal*, McGraw-Hill Publishing Company; A. M. Dudley (A'08, F'13,) Westinghouse Electric and Manufacturing Company; F. M. Farmer (A'02, F'13, president) vice-president and chief engineer, Electrical Testing Laboratories; W. H. Harrison (A'20, F'31, past president), vice-president and chief engineer, American Telephone and Telegraph Company; and G. P. Sawyer, Cerro de Pasco Copper Corporation.

Inaugurated in 1936 to recognize "meritorious service in the interests of their fellowmen," the Eta Kappa Nu award, is given to electrical engineers graduated not more than 10 years, and less than 35 years of age. Careful consideration is given to civic, social and cultural activities, as well as to technical achievements, in making the final choices.

The annual award dinner will be held in New York on Monday evening, January 22, the first day of the AIEE winter convention, in order to afford an opportunity for out-of-town Institute members to attend. Mr. Meacham will be presented with a small replica of the large bronze bowl which stands in the trophy case at Institute headquarters and on which his name will be engraved.

Southern District Executive Committe Meets

The annual meeting of the executive committee of AIEE District 4 was held at Atlanta, Ga., November 25, 1939. Those present were:

F. R. Maxwell, Jr., vice-president, District 4
A. S. Hoefflin, secretary, District 4
S. W. Anderson, vice-chairman, District 4, national membership committee
L. L. Patterson, chairman, District committee on student activities
W. W. Hill, chairman; T. H. Mawson, secretary; Alabama Section
K. E. Hapgood, chairman; W. G. Parrott, Jr., secretary; East Tennessee Section
J. Coleman Jones, chairman, Florida Section
J. O'D. Shepherd, chairman; J. M. Flanigen, secretary; T. W. Fitzgerald; Georgia Section
J. M. Houchens, chairman; J. F. Miller, secretary; Louisville section
George F. Leake, chairman, Memphis Section
B. M. Anthony, vice-chairman; H. W. Hutchcraft, secretary; Muscle Shoals Section
F. E. Johnson, secretary, New Orleans Section
F. S. Fouraker, chairman, North Carolina Section
F. W. Smith, chairman; L. Saunders, secretary; Virginia Section

Vice-President Maxwell presided. An invitation to the national board of directors to hold the 1941 summer convention of the AIEE at Atlanta, Ga., was prepared and approved. The committee expressed its approval of the proposal of the Middle Eastern District that the 1941 winter convention be held in Philadelphia. The question of a District meeting was referred to the District co-ordinating committee for study and recommendation.

J. Coleman Jones was elected to represent the District on the national nominating committee. He was given no instructions by the committee.

During discussion of Section activities, it was agreed that Sections scheduling outstanding speakers should notify the District secretary, in order that other Sections and Branches might, if they desired, arrange meetings for the same speaker.

The following were appointed as members of the District co-ordinating committee:

J. M. Flanigen, K. E. Hapgood, F. E. Johnson, J. O'D. Shepherd, L. L. Patterson; ex officio, F. R. Maxwell, Jr., and A. S. Hoefflin.

A committee was appointed to draw up suitable resolutions in memory of E. D. Wood, vice-president of the District before his death November 9, 1939. Other topics of District interest were discussed.

Buckley Succeeds Beggs as Foundation Chairman

Following the death on November 23, 1939, of Professor G. E. Beggs, newly elected chairman of The Engineering Foundation, O. E. Buckley (M'19, F'29) vice-chairman of the Foundation, was elected chairman by the action of the executive committee of the organization. F F Colcord was elected vice-chairman, and W. I. Slichter (A'00, F'12) one of the AIEE representatives on the board of trustees, was elected to fill the vacancy on the executive committee. K. H. Condit was made chairman of the research procedure committee, of which Doctor Buckley becomes a member ex officio. and E. M. T. Ryder was appointed to complete the membership of the committee.

A full list of the officers, trustees, and committees of Engineering Foundation appeared in the December 1939 issue, page 531. A biographical sketch of Doctor Buckley appeared in the same issue, page 537, in connection with his appointment as vice-chairman of the Foundation.

Future Meetings of Other Societies

American Chemical Society. Annual meeting, April 8–12, 1940, Cincinnati, Ohio.

American Institute of Mining and Metallurgical Engineers. 152d annual meeting, February 12–15, 1940, New York, N. Y.

American Physical Society. 233d meeting, February 22–24, 1940, New York, N. Y.

American Society for Testing Materials. Committee week and spring meeting, March 4–8, 1940, Detroit, Mich.

American Society of Civil Engineers. Annual meeting, January 17–20, 1940, New York, N. Y.

American Society of Heating and Ventilating Engineers. 46th annual meeting, January 22–26, 1940, Cleveland, Ohio.

American Society of Refrigerating Engineers. Annual meeting, January 17–19, 1940, Chicago, Ill.

Electrochemical Society. Spring meeting, April 24–27, 1940, Wernersville, Pa.

National Electrical Manufacturers Association. Mid-winter conference, February 5–9, New York, N. Y.

Society of Automotive Engineers. Annual meeting, January 15–19, 1940, Detroit, Mich.

New Heads for General Electric Company

RETIREMENT of Gerard Swope (A'99, F'22) president, and Owen D. Young, chairman of the board, was announced at a recent meeting of the directors of the General Electric Company. New officers elected at that time, who assumed their duties January 1, are Charles E. Wilson, formerly executive vice-president, who becomes president, and Philip D. Reed, formerly assistant to the president, who becomes chairman of the board. Shown here from left to right are Mr. Young, Mr. Reed, Mr. Swope, and Mr. Wilson. Mr. Wilson began his career in 1899 as office boy for Sprague Electric Company, former constituent company of G.E., and has since served in most functions of the organization and in many capacities, becoming executive vice-president in 1937. Mr. Reed, who is an electrical-engineering graduate (University of Wisconsin, 1921) and a member of Tau Beta Pi, holds the degree of doctor of laws from Fordham University. He entered General Electric's law department in 1926, and was made assistant to the president in 1937. Mr. Young and Mr. Swope, both of whom assumed their positions in 1922, have been made respectively honorary chairman of the board and honorary president. A biographical sketch of Mr. Swope appears on page 47.

"Engineering Audits" Proposed for Public Works

A proposed "Public Projects Efficiency Bill" was described by State Senator Thomas C. Desmond of Newburgh, N. Y., before a luncheon meeting of the American Institute of Consulting Engineers held in New York City, December 6, 1939. The bill is intended to encourage, and specifically to permit, state and local units of government to hire independent engineers "of outstanding reputation . . . to double check in advance the economy, safety, desirability, feasibility, and efficiency of public works projects." The bill is intended specifically to enable the procurement of an independent estimate of the extent of the benefit, if any, that may be expected to accrue to the public as the result of such public works, either generally or as compared with their probable cost.

The bill provides that findings of the independent engineers, although not binding on the unit of government concerned, must be made public, thus revealing any unsound or undesirable features so that the public may take action accordingly. Characterizing the Florida Ship Canal and Passamaquoddy power projects as "outstanding national examples of waste of public moneys which intelligent engineering advice in advance would have prevented," Senator Desmond described his bill as being "aimed toward reduction in the cost of government and designed to insure social and economic as well as engineering soundness in public works projects." He stated further that "the checks provided by this bill on the work of those proposing public works projects are similar to those which auditors make of the accounts of financial officers. Financial audits stimulate accuracy and so will engineering audits."

The Senator expressed the hope that his bill would serve as a model for other states.

Doctor D. C. Jackson (A'87, F'12, past president) of Cambridge, Mass., presided at the luncheon as president of the American Institute of Consulting Engineers.

Columbia Establishes Egleston Medal

The Egleston Medal, commemorating Professor Thomas Egleston, pioneer in engineering education, has been established by the Columbia University Engineering Schools Alumni Association, to be awarded annually to an alumnus who has "distinguished himself either in the furtherance of his branch of the profession in the development of processes or of technique, or in the application of engineering principles."

The first awards were made in 1939, in connection with the celebration of the 75th anniversary of the School of Engineering, to 12 outstanding graduates. Gano Dunn (A'91, F'12) president of the J. G. White Engineering Corporation and of Cooper Union, was one of those honored. A biographical sketch of Doctor Dunn appeared in the November 1939 issue, page 489

Honorary Members Named by Civil and Mechanical Engineers

The American Society of Civil Engineers and The American Society of Mechanical Engineers have each recently conferred honorary membership upon several distinguished engineers.

The ASCE has named the following, all members of the society:

W. J. E. Binnie, senior partner of Sir Alex. Binnie Son and Deacon, London, Eng., and president of The Institution of Civil Engineers of Great Britain.

J. M. R. Fairbairn, retired chief engineer of the Canadian Pacific Railway, Montreal, Que., Can.

H. S. Crocker, consulting engineer, Denver, Colo.

H. S. Jacoby, Washington, D. C., professor emeritus of bridge engineering at Cornell University

T. U. Taylor, dean emeritus of engineering at University of Texas, Austin

Formal presentation of certificates of honorary membership will be made at the annual meeting of ASCE, New York, N. Y., January 17–20, to all except Mr. Binnie, whose certificate will probably be presented in England at some later time.

Named by ASME were:

D. S. Kimball, dean emeritus of engineering, Cornell University, Ithaca, N. Y.

E. J. Prindle (A'06, M'20) retired patent attorney and mechanical engineer, East Orange, N. J.

C. T. Main, industrial engineer, Boston, Mass.

H. H. Vaughan, consulting engineer and president, Canadian Foreign Investment Corporation, Montreal, Que., Can.

Certificates were presented at the annual meeting of the society at Philadelphia, Pa., December 4–8, 1939. A biographical sketch of Mr. Prindle appears on page 48.

Also at the recent meeting, the ASME Gold Medal, highest honor of the society, was presented to J. E. Gleason, president, Gleason Works, Rochester, N. Y., for "distinguished service to the automotive industry by making possible better and safer gear drives."

Registration at the first ASME annual meeting to be held elsewhere than in New York City was 2,224. The banquet held in connection with the meeting was the largest in the society's history. An unusually large number of technical papers, over 100, were presented, with particular interest shown in the subject of power generation.

Engineering Education Report Issued by ECPD

That the engineering school, for years a stepchild of the university, has fought its way upward and stands today on the level of the university and in some cases on an even higher level is the general theme of the report on "Present Status and Trends of Engineering Education in the United States," by Doctor Dugald C. Jackson, (A '87, F '12) emeritus professor of Massachusetts Institute of Technology, issued November 25, 1939, by the Engineers' Council for Professional Development, with the aid of funds supplied by the Carnegie Foundation for the Advancement of Teaching. The report is one of the valuable by-products of the task of accrediting curricula in engineering that has been accomplished with such notable success during the last few years by the committee on engineering schools of ECPD.

Doctor Jackson's report may be divided roughly into four parts, to which an appendix has been provided by Allen W. Horton, Jr., who acted as secretary to the committee during the period in which the accrediting procedure was developed and put to the test and the data were collected. In the early chapters of the report Doctor Jackson traces the history of developments that led up to the accrediting program, summarizes the Mann, Wickenden, and Potter reports that have played important roles in that development, and sketches briefly the status of engineering education in America in 1939. He next turns his attention to the committee on engineering schools of ECPD, to the procedure it adopted in its task of accrediting curricula, and to comments on some of the perplexing problems it had to face and the progress of the committee's own thinking and methods that resulted from study of these problems.

The data themselves, which cover 679 curricula in 139 institutions, assembled, coordinated, and analyzed in the form of tables and charts, with Doctor Jackson's comments on what they signify to him, occupy the third portion of the report. These data were gathered for the purpose of the accrediting program, which they usefully served, but their very existence constituted such a rich store of information of value to engineers and educators, and was so fruitful for the improvement of engineering education, that the committee was able to secure from the Carnegie Foundation for the Advancement of Teaching the funds necessary to put them in shape for public use.

Copies of the paper-bound report, which contains 177 pages, may be obtained for $1 each from the Engineers' Council for Professional Development, 29 West 39th Street, New York, N. Y.

Current Items From American Engineering Council

Joint Committee Studying Future of AEC

Organization of the special joint committee formed to consider the future form and scope of American Engineering Council took place at its first meeting, held November 27, 1939, in New York, N. Y. The group, appointed at the suggestion of Council's president and executive committee, includes three representatives of each of the three founder societies that are Council's chief supporters—the American Society of Civil Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers—plus three men representing AEC. All members were present and, in addition, Council's President William McClellan and Secretary F. M. Feiker.

The meeting opened with a statement by Doctor McClellan outlining the background leading to the call for formation of the committee. He discussed the need for professional unity among engineers and the necessity for having some interprofessional body to advance the public understanding of the profession of engineering, with special reference to the part that engineers should play in solving social and economic questions upon which they are peculiarly qualified to advise. American Engineering Council, he pointed out, is not a superorganization, but a functional service group for its members that is devoted to public service rather than to the specialized technical and engineering problems of the respective engineering societies. This membership now comprises over 50 national, state, and local technical organizations.

Doctor McClellan then reviewed the constant difficulties experienced in financing the work of AEC, in keeping the rank and file of member societies informed as to its accomplishments, and in meeting the many opportunities for service presented to Council, many of which must of necessity be deferred because of lack of funds.

A lengthy discussion followed Doctor McClellan's talk, from which emerged a number of major ideas that may be summed up as follows:

1. Some organization is essential, similar in character to the American Medical Association and the American Bar Association, to work toward the dual objectives of interprofessional relations among engineers and a combined professional approach to public problems.

2. The present AEC represents one method of providing such a body.

3. There should be closer co-ordination between the activities of AEC in its specialized public relations field and the various committees of its member organizations set up for similar or co-ordinate objectives such as, for example, the general advance of professional standards and the economic status of engineers, and interrelations between education and engineering.

4. The engineering profession as a whole has yet to find a means of advising the younger engineers on questions involving their future professional status.

The committee then organized, electing Doctor John C. Parker (AIEE A'04, F'12) chairman and T. F. Barton (AIEE A'12, F'30) secretary. Three subcommittees were authorized to consider questions of membership, scope, and finance, and to be headed, respectively, by Malcolm Pirnie, (ASCE), Harold M. Lewis (ASCE), and John S. Dodds (AEC). To meet the immediate financial situation it was recommended that each of the three founder societies contribute not less than $8,300 to AEC during the year 1940.

U. S. Calls Parleys on Power Grid System

Starting on December 5 the National Power Policy Committee, of which Secretary of the Interior Harold L. Ickes is chairman, began a series of conferences in Washington with the officials of some 50 large public utility companies operating in the eastern part of the United States for the purpose of exploring the possibilities of constructing a series of high-voltage power lines tying together the larger generating plants and power-consuming centers in this area, including both private and public developments.

While no definite plan has been made public, the proposal envisions connecting links that would make it possible to interchange power whenever necessary between such major load centers as Boston, New York, Philadelphia, Washington, Buffalo, Cleveland, Detroit, Chicago, St. Louis, and possibly Birmingham, as well as intervening cities. Connections would be made with all major generating stations, both steam and hydro, without regard to whether they are controlled by private capital, municipalities, or the Federal Government. Construction would cost in the neighborhood of $500,000,000, according to preliminary estimates.

A similar plan has been in operation in England for a number of years, being popularly known as the grid system. Its application to this country is proposed as a method of providing greater flexibility in meeting power demands resulting from future industrial expansion, particularly in case of war. Critics of the plan, as applied here, protest that there is now, in existence or under construction, ample generating capacity in each of the localities to meet all predictable future demands, and that the expenditure of such a large amount would impose an unnecessary financial burden upon consumers of electricity. Its proponents take the view that the future growth of power demand will be at an accelerating rate and that the rate of construction can be adjusted to actual needs for the new facilities. They are also understood to be relying strongly on the national defense argument, on the assumption that, even though temporarily uneconomic, the grid can be justified as a safeguard against the power shortages experienced by American industry during the last war.

If it be assumed that the economic objection is sound, and the grid plan is nevertheless adopted, the private utilities will be facing a dilemma. They will be forced to choose between themselves financing and constructing unneeded facilities, or letting the government do so and thus taking one more step in the direction of public ownership of power facilities. In England the grid is operated by an independent board composed of representatives of both public and private operating companies, and it is possible that some similar system of control might be worked out in this country, but this solution would have numerous difficulties to hurdle.

Standards

Rubber-Insulation Standard Withdrawn. Under date of August 11, 1939, the American Standards Association issued notice that on recommendation of sectional committee *C*8, "Insulated Wires and Cables," the American Standard entitled "Specifications for Class *A* 30 Per Cent Rubber Insulation for Wire and Cable for General Purposes," *C*8.4 (1936) has been withdrawn. The action of the ASA is based on the fact that the standard had dropped out of general use, having been displaced by *C*8.17 "Class *OA* 30 Per Cent Rubber Insulation for Wire and Cable for General Purposes."

AIEE Representatives on Electrical Standards Committee. At the August meeting of the AIEE board of directors, the following representatives and alternates were appointed to serve on the electrical standards committee of the ASA: R. E. Hellmund, Westinghouse Electric and Manufacturing Company, V. M. Montsinger, General Electric Company, H. S. Osborne, American Telephone and Telegraph Company; Alternates: E. L. Moreland, Massachusetts Institute of Technology, E. B. Paxton, General Electric Company, H. E. Farrer, AIEE headquarters.

Basic Principles for Rating of Electrical Machinery and Apparatus. Co-ordinating committee 4 of the standards committee, P. L. Alger, chairman, held a session at the AIEE Middle Eastern District meeting in Scranton, Pa., October 11, 1939. A final report may be ready for publication in January 1940.

Joint Committee on Insulation Co-ordination. At the October 17 meeting of the AIEE standards committee, an invitation was presented suggesting that the Institute co-operate in the work of a joint committee of Edison Electric Institute and National Electrical Manufacturers Association now dealing with the subject of insulation co-ordination. The standards committee recommended the appointment of four men to serve on the joint committee. This recommendation was approved by the board of directors on October 27, 1939. The appointments made were as follows: Stanley Stokes, Union Electric Company of Missouri, R. T. Henry, Buffalo Niagara Electric Corporation, A. C. Monteith, Westinghouse Electric and Manufacturing Company, D. M. Jones, General Electric Company.

Standard Voltages and Currents. Co-ordinating committee 2 of the AIEE standards committee, under the chairmanship of C. A. Powel, Westinghouse Electric and Manufacturing Company, made its preliminary report at the October 17, 1939, meeting of the standards committee on "voltages below 100." A thorough survey of the field is being made by a subcommittee under D. F. Miner. A questionnaire has been sent out for the purpose of assembling existing information. Data have already been received from a number of fields, including the following: central stations, signaling, railways and busses, therapeutic devices, telephone, welding, lighting, portable tools and devices, electronic devices. This preliminary survey indicates that there are now 42 well-established voltages in use in the United States in the range of 1 to 100 volts. There appear to be very few standards at present even for specific types of apparatus.

Letter Symbols for Electric and Magnetic Quantities

Abstracted From a Report Prepared as a Proposed Revision of AIEE Standard 17*g*1 and Soon to Be Available in Printed Report Form for Criticism (See Accompanying Text)

Quantity	Letter Symbol*	Name of Unit
Admittance	Y, y	mho
Angular frequency Angular velocity	ω	
Capacitance	C	farad, microfarad, micro-microfarad
Capacity (see capacitance)	C	
Charge, quantity	Q	
surface density of	σ	
volume density of	ρ	
Conductance	G, g	
Conductivity	γ	
Coupling coefficient	κ	
Current	I, i	ampere, milliampere
Current density (see linear current density)	S	
Difference of potentials	E, e	volt, microvolt, kilovolt
Dielectric constant	K, or ϵ	
Dielectric constant of free space	K_0, or ϵ_0	
Dielectric flux	Ψ	
Dielectric flux density	D	
Efficiency	η	
Elastance	S	
Electric displacement	D	
Electric potential	E, e	volt
Electric tension (see voltage)	E, e	
Electric intensity	$\mathcal{E}$	
Electric field intensity	$\mathcal{E}$	
Electromotive force	E, e	volt
Electrostatic capacity (see capacitance)	C	farad
Electrostatic flux density	D	
Electrostatic induction	D	
Energy (see also work)	W	joule, watt-hour
Flux density:		
electrostatic	D	
magnetic	B	gauss
Flux, dielectric	Ψ	
magnetic	Φ	maxwell, weber
Frequency	f	cycle per second, hertz
Frequency, rotational	n	
Impedance	Z, z	ohm
Inductance, self	L	henry
Inductance, mutual	M $L_{1,2}$	henry
Intensity of magnetization	J	
Linear current density	A	
Magnetic field strength	H	oersted
Magnetic flux	Φ	maxwell, weber
Magnetic flux density	B	gauss
Magnetic induction	B	gauss
Magnetic intensity	H	oersted
Magnetizing force	H	oersted
Magnetomotive force	M	ampere-turn, gilbert
Number of conductors	N	
Number of turns of a winding	N	
Number of poles	p	
Number of phases	n or m	
Period	T	
Permeability	μ	
of free space	μ_0	
Permeance	Λ	
Permittance (see capacitance)	C	
Permittivity (see dielectric constant)	K, ϵ	
Phase angle	φ	
Power, active	P (P_p) p	watt
apparent	None yet agreed on	
reactive	Q (P_q)	var
Quantity of electricity	Q	coulomb
Reactance	X, x	ohm
Resistance	R, r	ohm
Resistivity	ρ	ohm-centimeter
Reluctance	θ	
Reluctivity	ν	
Rotational frequency	n	
Self-inductance	L	henry
Slip	s	
Space permeability	μ_0	
Specific inductive capacity	K or ϵ	
Susceptance	B, b	mho
Susceptibility	κ	
Speed of rotation	n	
Temperature	t, θ	degree
Temperature, absolute	T	degree
Time	t	second
Time constant	τ	
Voltage	V, v; E, e	volt
Work (see energy)	W, w	erg, kilowatt-hour

* All letter symbols are to be printed in *italic* letters, except when used as vectors, which are printed in **bold face** letters.

NOTES: 1. Where distinctions between maximum, instantaneous, effective (root-mean-square), and average values are necessary E_m, I_m, and P_m are recommended for maximum values; e, i, and p for instantaneous values, E and I for effective (rms) values, and P for average value.

2. It is recommended that quantities per unit volume, area, length, etc., be represented as far as practical by lower-case letters, corresponding to upper-case letters which will represent the total quantities.

3. Where a distinction between electromotive force and difference of potential is necessary or desirable, the symbols E, e and V, v, respectively, may be used.

Precipitation Rate on Flashover Tests. For quite a number of years a conflict has existed in the AIEE standards in the specification of the precipitation rate for wet flashover. The insulator standards have specified 0.2 inch per minute precipitation whereas the corresponding tests on bushings are to be made at an 0.1-inch rate. This matter was referred by the standards committee at the October 17 meeting to co-ordinating committee 3 (insulation testing and co-ordination) for consideration and report to the standards committee.

Organization of Sectional Committee on Voltages Below 100. An invitation has been received by the AIEE from the ASA suggesting the appointment of representatives to serve on a sectional committee on "Standardization of Voltages Below 100." The following appointments were recommended and have been approved by the board of directors: D. F. Miner, Carnegie Institute of Technology, A. M. de Bellis, Consolidated Edison Company of New York, Inc., A. H. Schirmer, Bell Telephone Laboratories, Inc. The AIEE subcommittee on voltages below 100 referred to in an earlier paragraph will co-operate with the sectional committee when it gets under way.

New Representatives on Sectional Committee on Wires and Cables. Because of the resignation of J. B. Whitehead and the death several years ago of E. B. Meyer, the standards committee, at its meeting of October 17, recommended the appointment of two representatives to serve with W. A. DelMar, chairman of the AIEE delegation. The recommendations approved by the directors were as follows: C. L. Dawes, Harvard University, and W. N. Zippler, Gibbs and Cox, Inc.

Sponsorship for Welding Goes to AWS. The Institute and NEMA have resigned their joint sponsorship of the sectional committee on electric welding apparatus, *C*52, in favor of a sole sponsorship by the American Welding Society. It is hoped that the sectional committee will shortly undertake a revision of the two existing American Standards, *C*52.1 and *C*52.2 "Electric Arc Welding Apparatus" and "Resistance Welding Apparatus."

New Representatives on Rotating Electrical Machinery. To fill the vacancy in the AIEE delegation on the sectional committee on rotating electrical machinery made by the death of A. E. Kennelly, the standards committee at its meeting of October 17 recommended the appointment of Reinhold Rudenberg, of Harvard University. This appointment was confirmed at the October meeting of the directors.

Revision of Letter Symbols for Electric and Magnetic Quantities. Sectional committee *Z*10 "letter symbols and abbreviations for science and engineering" submitted through its chairman, J. Franklin Meyer, at the October 17 meeting of the standards committee, a revised report of the present AIEE standard 17*g*1. On recommendation of Doctor Meyer, the standards committee accepted the report for publication in pamphlet form as a suggested revision of the existing AIEE and American standard. An abstract of the report presenting a list of quantities with recommended symbols appears elsewhere in this section. For purpose of criticism, copies of the complete report will be available in January and may be had without charge on application to H. E. Farrer, secretary, AIEE standards committee, 33 West 39th Street, New York, N. Y.

There is one particularly notable development in this report; it is the inclusion of a statement on "general principles". Identical statements will be included in all other subcommittee reports of the sectional committee. The statement is drawn up as a guide to authors in the use of symbols.

Personal Items

F. M. Feiker (M'34) since 1934 executive secretary of American Engineering Council, has been appointed dean of engineering of George Washington University, Washington, D. C., according to an announcement received as this issue of Electrical Engineering goes to press. A biographical sketch of Doctor Feiker will appear in the February issue.

Philip Torchio (A'95, F'12) retired vice-president, Consolidated Edison Company of New York, Inc., has been awarded the Edison Medal for 1939. The medal, highest honor of the AIEE, will be presented on Wednesday evening, January 24, at the winter convention. It is awarded to Mr. Torchio for "distinguished contributions to the art of central-station engineering and for achievement in the production, distribution, and utilization of electrical energy." He was born at Vercana, Como, Italy, August 2, 1868, and received the degree of bachelor of arts at the University of Pavia, 1890, and the degrees of mechanical engineer and electrical engineer from the Royal Polytechnic of Milan, having taken a special electrical-engineering course at the Institute Carlo Erba. He came to New York in 1893 and was employed as draftsman and chief draftsman by the Sprague Electric Elevator Company, 1893–95. In 1895 he joined the engineering staff of the Edison Electric Illuminating Company of New York, continuing with that company and its successors, the New York Edison Company and Consolidated Edison Company of New York, until his retirement in 1938. He held the positions of engineer of economics, 1895–1901; engineer of distribution, 1901–05; chief electrical engineer, 1905–24; vice-president 1924–38, and from 1905 to 1938 was also consulting engineer for five allied companies. He has made numerous contributions to technical literature, has been member and chairman of many AIEE technical committees, and is also a member of the Franklin Institute, Illuminating Engineering Society, Associazione Elettrotechnica Italiana, and New York Electrical Society (past president).

PHILIP TORCHIO

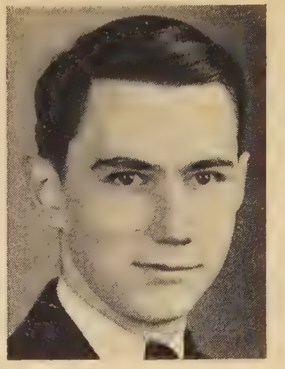
Gerard Swope (A'99, F'22) has retired as president of the General Electric Company, Schenectady, N. Y. He was born at St. Louis, Mo., December 1, 1872, received the degree of bachelor of science in electrical engineering at Massachusetts Institute of Technology in 1895, and has received the honorary degrees of doctor of science from Rutgers University (1923), Union College (1924), Washington University (1932); doctor of laws, Colgate University (1927), and doctor of engineering, Stevens Institute of Technology (1929). His first engineering experience was as a helper at General Electric Company, Chicago, Ill., in 1893. In 1895 he was employed by Western Electric Company, Chicago, becoming manager of the St. Louis office, 1899; in 1906 he returned to Chicago and in 1908 went to New York as general sales manager, becoming vice-president and director in 1913. During the World War he was a member of the general staff of the United States Army, serving as assistant director of purchases, storage, and traffic. In 1919 he was made president of International General Electric Company. He became president of the General Electric Company in 1922, and since 1927 has been chairman of the board of International General Electric. He is also a member of various other scientific and engineering societies. Mr. Swope was recently appointed chairman of the New York City Housing Authority, and will assume the duties of that position about March 1.

L. F. Morehouse (M'16, F'20) has retired as technical representative in Europe for American Telephone and Telegraph Company and Bell Telephone Laboratories. He was born October 21, 1874, at Big Rapids, Mich., and received the degrees of bachelor of science in electrical engineering (1897) and master of arts (1904) and the honorary degree of doctor of engineering (1934) from the University of Michigan. Between 1897 and 1904 he was engaged in graduate study and was an instructor in physics, at Washington University, St. Louis, Mo., 1901, and at the University of Michigan, Ann Arbor, 1902–04. He was instructor and later assistant professor of electrical engineering at Michigan 1904–06. In 1906 he went to London, Eng., as transmission engineer for Western Electric Company, returning to New York, N. Y., in 1909 as equipment engineer for the American Telephone and Telegraph Company. In 1919 he became equipment development engineer for the company, and in 1933 assistant director of systems development for Bell Telephone Laboratories. He has been European representative for the two organizations with headquarters in London, England, since 1935. Doctor Morehouse was a manager of the AIEE 1919–23, and vice-president 1924–26. He is also a member of the American Association for the Advancement of Science, The Institution of Electrical Engineers of Great Britain, Sigma Xi, and Tau Beta Pi.

J. E. Hobson (A'36) central-station engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been awarded honorable mention in the selection by Eta Kappa Nu, honorary electrical-engineering society, of America's outstanding young electrical engineer for 1939. A native (1911) of Marshall, Ind., he received the degrees of bachelor of science (1932) and master of science (1933) in electrical engineering from Purdue University, and doctor of philosophy (1935) from California Institute of Technology. He was a graduate assistant and teaching fellow at the latter institution 1933–35; assistant professor of mathematics, Earlham College, Richmond, Ind., 1935–36; and instructor in electrical engineering, Armour Insitute of Technology, Chicago, Ill., 1936–37. Since 1937 he has been with the central station section of the Westinghouse industry-engineering department. He is also a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.

E. J. Prindle (A'06, M'20) retired patent attorney and engineer, East Orange, N. J., has been made an honorary member of The American Society of Mechanical Engineers. He was born at Washington, D. C., November 5, 1868, and received the degrees of mechanical engineer, Lehigh University, 1890, and bachelor of laws, 1902, master of laws, 1904, from the National University, and the honorary degrees of doctor of laws, 1930, National University, and doctor of engineering, 1934, Lehigh University. From 1890 to 1899 he was an assistant examiner in the United States Patent Office, Washington, D. C., leaving that position to enter the practice of patent law, which he continued in Washington, D. C., until 1905 and in New York until his recent retirement. He was senior member of the firm of Prindle, Wright, Neal, and Bean. He is also a member of the ASME, American Institute of Mining and Metallurgical Engineers, other technical societies, and various legal organizations, and was for many years chairman of the patents committee of American Engineering Council.

C. E. Shannon (A'39) assistant in mathematics, Massachusetts Institute of Technology, Cambridge, has been awarded the Alfred Noble prize for his paper "A Symbolic Analysis of Relay and Switching Circuits." The award, an account of which appears on page 42, will be presented during the AIEE winter convention in New York, N. Y., January 22–26. Mr. Shannon was born April 30, 1916, at Petoskey, Mich., and received the degree of bachelor of science in electrical engineering from the University of Michigan, 1936. Since 1936 he has been engaged in graduate study at MIT, at the same time acting as a research assistant in electrical engineering, 1936–38; research assistant on a special project summer of 1938; and assistant in mathematics, 1938–39. He is also a member of the Institute of Radio Engineers and of Sigma Xi, and was an Enrolled Student in the AIEE when the prize-winning paper was presented and published.


C. E. SHANNON

C. K. Gieringer (A'35) chief electrical engineer, Liebel-Flarsheim Company, Cincinnati, Ohio, has been awarded honorable mention in the selection by Eta Kappa Nu, honorary electrical-engineering society, of America's outstanding young electrical engineer for 1939. A native (1907) of Miamitown, Ohio, he holds the degrees of electrical engineer (1932) and master of electrical engineering (1934) from the University of Cincinnati. He was an assistant in the research laboratory of the Detroit (Mich.) Edison Company, 1930–32 and a teaching fellow at the University of Cincinnati, 1932–34, and since 1934 has been with the Liebel-Flarsheim Company, as experimental electrical engineer, and chief electrical engineer. He received the Middle Eastern District prize for initial paper in 1934 for a paper on "A New A-C Null Indicator." He is also a member of the Institute of Radio Engineers, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

D. C. Hosfeld (A'15, M'31) has retired as plant employment engineer, American Telephone and Telegraph Company, New York, N. Y. He was born in Shippensburg, Pa., September 10, 1883, and educated in Virginia. In 1897 he became an installer for the Bell Telephone Company of Pennsylvania, at Shippensburg. He continued with that company as equipment installer, 1901; wire chief, 1907; plant superviser, 1908; district plant superintendent, 1911; plant methods superintendent, 1920; and division equipment superintendent, 1922. In 1925 he went to Montreal, Que., as division plant superintendent for the Bell Telephone Company of Canada, and the following year became plant results engineer for the American Telephone and Telegraph Company, continuing in that position until 1937. He has since been plant training engineer and plant employment engineer.

Gano Dunn (A'91, F'12) president, J. G. White Engineering Corporation, New York, N. Y., and president of Cooper Union for the Advancement of Science and Art, was one of 12 outstanding engineering graduates of Columbia University to be awarded the Egleston Medal presented for the first time in 1939 by the Columbia Engineering Schools Alumni Association for distinguished engineering achievement. A biographical sketch of Doctor Dunn appeared in the November 1939 issue, page 489.

J. C. Parker (A'04, F'12) has been elected chairman of the committee recently appointed to consider the future form and scope of American Engineering Council. Doctor Parker, who is a vice-president of Consolidated Edison Company of New York, Inc., New York, N. Y., was president of the Institute 1938–39 and is currently chairman of its committee on planning and co-ordination.

O. E. Buckley (M'19, F'29) executive vice-president, Bell Telephone Laboratories, Inc., New York, N. Y., has been elected chairman of The Engineering Foundation by the organization's board, following the death of G. E. Beggs, newly elected chairman. A biographical sketch of Doctor Buckley, who had just been made vice-chairman of the Foundation, appeared in the December 1939 issue, page 537.

A. W. Pride (A'20) has been made manager of the porcelain department of Westinghouse Electric and Manufacturing Company at Emeryville, Calif. He was formerly sales manager of the porcelain and transformer departments and will continue as sales manager of the latter. He has been with the company continuously since 1922, and from 1915 to 1917 was in the student training course and research laboratories at East Pittsburgh, Pa.

T. F. Barton (A'12, F'30) vice-president, AIEE, and assistant manager of the New York district of General Electric Company, New York, N. Y., has been elected secretary of the committee recently formed to consider the future form and scope of American Engineering Council.

R. W. Beck (M'37) has been appointed consulting engineer by the Klickitat County, Wash., public utility district. He was formerly an electrical engineer on the Bonneville Project, Portland, Ore.

W. R. Minzner (A'38) formerly employed as instructor in mathematics, Northeastern University, Boston, Mass., is now employed as instructor in the electrical department of the Rochester (N. Y.) Athenaeum and Mechanics Institute.

C. S. Lumley (A'22, M'29) has been appointed district engineer by the Roller-Smith Company. His headquarters will be in Chicago, Ill. He was formerly electrical engineer for the Department of Public Works, City of Detroit, Mich., in charge of design of the city's new sewage-treatment plant.

E. T. B. Gross (A'34) formerly chief of the general engineering department, A. E. G.-Union Electric and Manufacturing Company, Vienna, Germany, has begun private consulting practice in Ithaca, N. Y. He had been associated with A. E. G.-Union, the Austrian division of General Electric Company, since 1924.

R. B. Kaufman (A'35) formerly research assistant, School of Engineering, Johns Hopkins University, Baltimore, Md., is now employed as an electrical engineer in the materials division of the United States Army Air Corps, Dayton, Ohio.

R. D. Miller, Jr. (A'34) formerly service manager, United Clay Products Company, Washington, D. C., has been appointed engineer, "B layout", Glenn L. Martin Company, Baltimore, Md.

A. W. Williams (A'39) has been employed as resident engineer, by the Valley Electric Membership Corporation, Natchitoches, La.

R. G. Boyles (M'34) former assistant manager of operation, Southern California Edison Company, Ltd., Los Angeles, Calif., has been appointed manager of operation. Mr. Boyles, who studied electrical engineering at Montana State College, has been with Southern California Edison since 1907, and became assistant manager of operation in 1934.

C. R. Benson (A'31) has been made official representative of the transformer department of the Pacific district of General Electric Company, with headquarters at Oakland, Calif. He was formerly meter and transformer specialist in the San Francisco office of the company.

L. T. Blaisdell (A'20, F'39) since 1936 commercial vice-president of General Electric Company, and manager of the southwestern district, with headquarters in Dallas, Tex., has been transferred to Cleveland, Ohio, as manager of the east central district. He has been associated with the company since 1904 and district manager in Dallas since 1924.

P. C. Schwantes, Jr. (A'24) has been appointed plant employment engineer, American Telephone and Telegraph Company, New York, N. Y. He was formerly plant results engineer and has been with A. T. and T. since 1924. From 1918 to 1924 he was with Western Electric Company.

J. H. Landwehr (A'19) formerly building and equipment engineer for eastern Missouri, Illinois, and Arkansas, Southwestern Bell Telephone Company, has been appointed general building and equipment engineer for the company, with headquarters at St. Louis, Mo.

A. S. Runciman (A'24, M'35) superintendent of transmission lines, Shawinigan Water and Power Company, Montreal, Que., Can., has been awarded an engineering alumni medal, for outstanding achievements in engineering, by the Council of the Engineering Alumni Association of the University of Toronto.

J. S. Wise (A'96, M'27) president, Pennsylvania Light and Power Company, Allentown, has been appointed a member of the committee on the development of Pennsylvania industry in the statewide job mobilization campaign.

C. M. Cavner (A'36) former assistant superintendent of substations, Southern California Edison Company, Ltd., Los Angeles, Calif., has been made superintendent of substations.

G. F. Maughmer (A'38) has been made manager of the Phoenix, Ariz., office of General Electric Company. He was formerly in the industrial and central stations departments of the company's Los Angeles, Calif., office.

R. E. Jerauld (A'21) has been made assistant to the manager of the Los Angeles, Calif., office of General Electric Company. He had been manager of the Phoenix, Ariz., office, since 1925, and has been with the company since 1905.

W. D. Howell (A'38) has been placed in charge of industrial power work in the San Francisco, Calif., office of Pacific Gas and Electric Company. He was formerly in the company's East Bay sales department at Oakland.

David Kalish (A'38) formerly assistant to chief engineer, Alliance Manufacturing Company, Alliance, Ohio, is now employed in the engineering department of the Curtiss Aeroplane Division, Curtiss-Wright Corporation, Buffalo, N. Y.

R. W. Masters (A'39) is a technical graduate assistant in the department of speech and phonetics, Ohio State University, Columbus, while studying for the master of science degree. He is on leave of absence from his position as junior engineer for RCA Manufacturing Company, Indianapolis, Ind.

H. L. Gerard (A'36) formerly electrical designer, Holway and Neuffer, engineers, Tulsa, Okla., is now superintendent of electrical distribution for the City of Kirkwood, Mo.

Fred Garrison (A'22, M'29) of the Los Angeles, Calif., central station department of General Electric Company, has been made meter specialist for the Pacific district.

C. S. Powell (A'38) formerly assistant electrician, Holly Sugar Corporation, Colorado Springs, Colo., is now assistant electrician at the Morony Dam of the Montana Power Company, Great Falls, Mont.

G. T. Dunklin (M'31) has been placed in charge of installment financing in the merchandising division of Westinghouse Electric and Manufacturing Company, New York, N. Y. He was formerly assistant sales manager of the division, and has been with the company since 1922.

W. M. A. Kern (A'26) formerly master mechanic, Chilean Nitrate Sales Corporation, Norfolk, Va., is employed as an electrician at the United States Naval Academy, Annapolis, Md.

R. M. Whaling (A'39) has been employed as serviceman by the International Business Machine Corporation, Sacramento, Calif.

A. L. Bohn (A'39) has been employed by the Bendix Radio Corporation, Baltimore, Md.

J. W. Pruett (A'39) is now employed as a junior engineer on the Bonneville Dam project, Portland, Ore.

S. G. Kelsey (A'39) is now junior electrical engineer for the National Advisory Committee for Aeronautics, Langley Field, Va.

L. P. Goetz (A'39) is now a valuation engineer for the Utah Power and Light Company, Salt Lake City.

Obituary

Stanley Sylvester Seyfert (A'05, M'13) head of the department of electrical engineering, Lehigh University, Bethlehem, Pa., died December 11, 1939. He was born March 19, 1881, at Strausstown, Pa., and received the degrees of bachelor of science, 1902, Kutztown State Teachers College; electrical engineer, 1904, master of science, 1909, Lehigh University; doctor of science, 1932, Massachusetts Institute of Technology. He joined the electrical-engineering department at Lehigh in 1904 as instructor, becoming assistant professor in 1909, associate professor, 1914, and professor, 1928. Since 1932 he had been head of the department and director of the curriculum. He was engineer for the Blue Mountain Electric Company, Bethel, Pa., 1907–17, and secretary and treasurer, 1917–27. He made a number of contributions to technical literature, held several patents, and was also a member of the Institute of Radio Engineers, Society for the Promotion of Engineering Education, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.

Harry S. Arnold (A'11) electrical and construction engineer Carleton Company, Inc., Brooklyn, N. Y., died July 24, 1939, according to information recently received at Institute headquarters. He was born in New York, N. Y., June 16, 1877, and took courses in various technical schools there. From 1895 to 1905 he was superintendent of electrical construction for the Commercial Construction Company, New York, after which he became an electrical inspector for the New York City Department of Education. In 1911 he became assistant electrical engineer for the department. During the period 1914–24 he was employed by various companies as construction electrical engineer, and also served in the United States Army Engineering Corps, 1917–19. He was a member of the M. J.

Daley Company, engineers and contractors, 1924–26, and 1926–29 engaged in electrical engineering and contracting with his own organization, the H. S. Arnold Company, Inc. During the next five years he had charge of design and installation of electrical systems of several large buildings in and near New York City, the most notable being the Chrysler building. In 1934 he was employed by the Federal Power Commission Washington, D. C., as engineer on its electric-rate survey, and two years later went with the Carleton Company. He was also a member of the Society of American Military Engineers, and of the New York State Society of Professional Engineers.

George Locke Crosby (A'15, M'26) vice-president and general sales manager, Roller-Smith Company, Bethlehem, Pa., died December 2, 1939. He was born at Brookhaven, Miss., July 19, 1883, and attended Millsaps College and George Washington University. He became sales engineer and manager of the Cleveland, Ohio, office of the Cutter Company in 1902, and in 1904 sales engineer for the Stanley G. I. Electrical Manufacturing Company. When the company was dissolved in 1905 he set up his own firm, Crosby, Craft, and Company, as selling agents for various companies, including the Roller-Smith Company. In 1910 he became sales engineer and manager of the Pittsburgh, Pa., office of that company, and in 1912 was transferred to the New York office. He became successively general sales manager, assistant to the president, and vice-president in charge of sales (1938). He moved to Bethlehem when the main office of the company was transferred there early in 1939. He was also a member of the Institute of Radio Engineers and the Society of Automotive Engineers.

Frank Powell Cox (A'01, M'02, F'13) retired manager of the West Lynn, Mass., works of the General Electric Company, died November 30, 1939. He was born at Terre Haute, Ind., December 31, 1866, and graduated in mechanical engineering from Rose Polytechnic Institute in 1887. He took a year of postgraduate work in electricity at Johns Hopkins University, and in 1889 was employed by the Kester Electric Company, Terre Haute. In the latter part of the same year he entered the testing department of the Thomson Electric Welding Company, at Lynn, Mass. The following year he was put in charge of the meter-testing department of the Thomson-Houston Company, successor to the preceding company and one of the forerunners of the General Electric Company, and some years later became engineer of the meter department of the latter. He became manager of the West Lynn works in 1920 and continued in that position until his retirement in 1935. He held a number of patents, mostly for meter improvements, and had contributed to technical literature and been active on several AIEE committees.

Fred James Cornford (A'23) construction engineer, Ohio Power Company, Power, West Va., died November 5, 1939. He was born at Brighton, Eng., June 9, 1885, and studied electricity at the London Polytechnic Institute. From 1899 to 1904 he was an apprentice with Page and Miles, electrical contractors, Brighton. Coming to New York, N. Y., in 1904 he became an electrician for S. Edward Eaton and Company, and three years later was employed by the B. and C. Electrical Construction Company, Utica, N. Y. From 1910 to 1914 he was with the Electric Shop, Inc., in Buffalo, N. Y., in charge of installation of electrical equipment in industrial plants and in the Buffalo Technical High School. During 1914–17 he was foreman of electrical construction for Woodmancy and Davidson, Chicago, Ill., and for F. Work, electrical contractor, Cleveland, Ohio. He was employed in 1917 by the American Gas and Electric Company, as general electrical foreman of construction at the Windsor power plant, Wheeling, W. Va., and continued with that company and various affiliates until about two years before his death, when he became associated with the Ohio Power Company.

Charles Crumer Hogshead (A'35) power engineer, Appalachian Electric Power Company, Roanoke, Va., died March 14, 1939, according to information recently received at Institute headquarters. He was born December 28, 1869, at Mount Crawford, Va. His electrical training was secured through correspondence courses. He was employed for some years by the Staunton, Va., street car company, later becoming assistant engineer of power plants for the Lynchburg (Va.) Traction and Light Company. While holding that position he spent some time with the Montgomery (Ala.) Traction Company, an affiliated organization. In 1907 he became chief engineer in charge of power plants for the Roanoke Railway and Electric Company, continuing in that position until 1925, when he became divisional power engineer in charge of power production and sales, for the Appalachian Electric Power Company, parent organization of the various operating companies by which he had been successively employed. He was an Associate of the Institute 1911–12, and was reinstated in 1935.

Ralph E. Sawyer (A'30) senior engineer, Equitable Gas Company, Pittsburgh, Pa., died October 29, 1939 at Buxton, Maine. He was born at Buxton, March 10, 1896, and was graduated from the University of Maine in 1917 with the degree of bachelor of science in electrical engineering. From 1917 to 1920 he was a traffic engineer with the American Telephone and Telegraph Company, New York, N. Y., later becoming a traffic engineer for the Ohio Bell Telephone Company, and in 1928 being transferred to the International Telephone and Telegraph Company. During the period 1931–35 he held various positions and in the latter year was appointed associate personnel research specialist for the Federal Resettlement Administration, on a survey of Administration personnel in the State of Louisiana. During 1936 he was employed as assistant valuation engineer by the New York State Public Service Commission and as engineer on the Federal Communications Commission's investigation of the American Telephone and Telegraph Company.

Louis Benedict Marks (A'90, M'95, F'13) retired consulting engineer in illumination, died at New York, N. Y., November 22, 1939. He was born at New York, January 25, 1869, and received the degrees of bachelor of science, 1888, from the College of the City of New York and of mechanical engineer, 1889, and master of mechanical engineering, 1890, from Cornell University. From 1890 to 1893 he was lighting expert with the Washington Carbon Company, Washington, Pa. In 1893 he invented and was granted basic patents on an "enclosed arc" lamp, for which he was awarded a gold medal at the Paris Exposition in 1900. During most of his career he was engaged in private consulting practice in illuminating engineering, having designed the lighting plans for many municipal, state, and Federal buildings. He was the first president of the Illuminating Engineering Society, elected in 1906.

Arthur E. Hecker (M'30) retired general manager of municipal utilities, Poplar Bluff, Mo., died June 1, 1939, according to information recently received at Institute headquarters. He was born May 14, 1878 at Pekin, Ill., and was educated there. From 1899 to 1901 he was electrician for the Corn Products Company, Pekin. He built and operated a light plant at Tallula, Ill., 1901–07, and in 1908 became supervising and erecting engineer for the Electric and Steam Engineering Company, contracting firm at St. Louis, Mo. He was operating manager at Roodhouse, Ill., 1911–12, and for the next four years manager of the light and power plant at Russellville, Ark. He went to Poplar Bluff in 1916 as supervising engineer for the City Department of Water and Light, and in 1917 became manager of municipal utilities, having charge of design, construction, and operation of both light and water systems. He had recently retired.

Augustine Leo Donnelly (A'18) general supervisor of testing section, Philadelphia Electric Company, Philadelphia, Pa., died recently, according to information just received at Institute headquarters. He was born in Philadelphia September 16, 1885, and received the degree of bachelor of science in electrical engineering from the University of Pennsylvania in 1909. After working for a short time for the Huntingdon Valley Electric Company, Wynnecote, Pa., he entered the student test course at General Electric Company in December 1909. In 1911 he entered the employ of the Philadelphia Electric Company as a testing engineer in the laboratory. He later became assistant supervisor, then supervisor of the testing laboratory, before becoming general supervisor of the testing department.

William LeRoy Robertson (A'05) technical assistant, Philadelphia Electric Company, Philadelphia, Pa., died November 17, 1939. He was born in Derby, Pa., October 15, 1883, and completed both the mechanical engineering course (1902) and the electrical engineering course (1904) at Drexel Institute. He had been employed by the Philadelphia Electric Company continuously since 1903, first as assistant in the laboratory and later as electrical engineer.

Section Activities

As Reported by Clifford A. Faust, Mansfield, Ohio, for the Sections Committee

◆

Cleveland, Akron, Mansfield Hold First Reunion

Nineteen years ago the Akron Section was formed, the members all being affiliated formerly with the Cleveland Section. Last March, the Mansfield Section was created from the previously organized Mansfield Division of the Cleveland Section. In view of the way the two younger Sections were formed, it was not surprising that the 1939–40 officers of all three Sections should strike on and quickly endorse the idea of holding an annual "family reunion."

The first joint meeting was held at the Portage Hotel in Akron November 14 and was pronounced a huge success. National Secretary H. H. Henline attended and gave an inspiring talk on the progress being made by the Institute. C. T. Sinclair, Institute vice-president for the Middle Eastern District, accepted an invitation to preside at the meeting. John R. Townsend, materials standards engineer of the Bell Telephone Laboratories, gave an interesting illustrated talk on "Application of High-Speed Motion Pictures to the Design of Mechanical Devices." And the festivities, which included a dinner before and refreshments after the speaking program, were enjoyed by 179 members and guests, 50 from Cleveland, 42 from Mansfield, and 87 from Akron. A feature of the meeting was a "head count," effected by having the members of each Section rise in turn.

Working a Year Ahead on Section Programs

Eight Sections of the Institute determine the programs for their meetings far enough in advance to enable them to distribute printed programs for the entire season prior to the scheduled date for the first meeting. These Sections—Michigan, Chicago, Lynn, Vancouver, Cleveland, Pittsfield, Springfield, and St. Louis—make their plans through the summer for the coming season, deciding on dates, selecting subjects for meetings, and actually engaging speakers. By arranging the meetings during the summer months, they are able to print the programs and distribute them to the members about September 1.

While considerable effort is required to plan all of the meetings for a season at one time, these Sections believe that it is more than worthwhile. In the words of one of the Section chairmen: "It places the Section in a favored position for securing speakers who are much in demand, removes the uncertainties which accompany 'short term' planning, provides members with a complete guide of activities for the season, and, of great importance, creates a feeling among the membership at large that the Section is being capably managed."

Aside from the full program for the season, the 12-page booklet currently issued by the Michigan Section gives the names of all officers and committee members and includes a complete roster of all members.

Chicago issues a large four-page folder which details the meetings for the season, gives a history of the Section, reports the number of members, cites the advantages of Section membership, invites the members to take part in committee work and to offer suggestions, and lists the names of committee members. A postcard is enclosed with the pamphlet for use by the members in proposing changes or additions in activities and for indicating their interest in committee work.

The Lynn Section presents season program, along with announcements, promotional material for certain meetings, names of the officers, and the membership committee personnel, in a six-page folder. A condensed schedule of meetings, including possible lectures, inspection trips, and technical sessions, is printed on a detachable $3^{1}/_{4}$- by $6^{1}/_{4}$-inch card.

A four-page blue folder is issued by the Vancouver Section, giving the complete schedule of meetings, listing the officers, and giving the names of all committee members. The folder gives the objective of the Institute, and states that members of kindred associations, teachers, students, and all interested are cordially invited to attend any meeting.

Cleveland issues a six-page folder listing all general meetings, and supplements this information with a complete schedule of the technical-division meetings. Names of all officers and committee chairmen are listed.

Pittsfield announces the subjects for its popular meetings and technical-lecture series on the first news letter issued in the fall. This letter also relates plans for the "Colloquia," monthly discussions which are led by qualified speakers.

Using a different plan from the others, the Springfield Section issues a stiff $2^{3}/_{4}$- by $4^{1}/_{2}$-inch card, designed to be carried in the pocket, giving the season program and listing the officers.

St. Louis follows the plan of giving all details for the year's meetings on the notice for the first meeting. The notice is printed on heavy stock and the list of meetings is confined to a 4- by 7-inch section of the notice, so that the list can be detached and retained for future reference.

Several other Sections follow the plan of giving details for one or two future meetings on the notices which are prepared for current meetings. The Wichita Section, for example, gives the details under the heading, "Prevue of Coming Attractions."

Washington and Maryland Hear Talk on Solar Energy

Members of the Washington and Maryland Sections held a joint meeting in the Capital City, November 14. After a dinner at the Hotel Harrington, the group assembled at the Natural History Building Auditorium where they heard a talk by Doctor C. G. Abbot, secretary of the Smithsonian Institute, on "Solar Energy". A total of 250 members and guests were present, 75 members from the Maryland Section, 115 from the host Section, 35 students, and 25 visitors.

Florida Electricals and Mechanicals Get Together

On October 21 the Florida Sections of the ASME and the AIEE joined the University of Florida Student Branches of the two societies for an afternoon and evening meeting, held at Gainesville. At the afternoon technical session D. P. Caldwell, division manager of the Florida Power and Light Company, Daytona Beach, spoke on "A Business Man's View of the Engineering Graduate," and L. G. Alexander presented a student paper on "The Sealed-Beam Headlight." The engineering laboratories of the University were visited at 4:30. An hour later the members enjoyed an old-fashioned barbecue, and in the evening they witnessed the Florida-Tampa football game. The meeting was one of the most successful ever held at Gainesville and was enjoyed by all who attended.

St. Louis Celebrates Its 300th Meeting

The November 15 meeting was a significant occasion for the St. Louis Section, for it was the 300th meeting of this 36-year old Section. Meeting notices carry the number of the meeting each time, so that when the 299th meeting was held the month previous the members began looking forward to the tricentennial event.

The principal speaker at the meeting was C. H. Giroux, head engineer, U. S. Engineers Office, Washington, who spoke on "The Bonneville Project." A total of 109 members and guests attended the meeting.

Oklahomans Inspect Fort Sill

Members of the Oklahoma City Section joined with members of the ASCE November 18 for one of the most interesting meetings ever held by the Section, an inspection trip to Fort Sill, the principal artillery school of the United States Army. At 3:00 p.m. the group inspected field-artillery equipment and at 3:30 Army engineers gave talks on the weapons which had just been seen. At 5:00 an inspection was made of the balloon and airplane hangers, and at 6:00 the engineers had supper at a battery mess. Following dinner, War Department training films were shown, providing a climax to a most interesting day.

Although Fort Sill is about 125 miles from Oklahoma City, many members from both societies made the trip.

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R. G. Thring
D. C. Vaughan
G. R. Wilhelm

WICHITA

H. K. Hentzen, Chm., Southwestern Bell Tel. Co., 301 N. Topeka St.
S. P. Campbell
I. S. Miller
C. R. Preston
E. H. Stephens

WORCESTER

Robert S. Horner, Chm., American Steel & Wire Co.
A. H. Magnuson
R. M. Peirce

◆

Mr. Institute Member:

To remain a healthy and robust organization, it is necessary for the Institute to acquire a steady influx of new blood among energetic engineers who have ambitions for continued advancement of the profession. You are informed each year, in the September issue of Electrical Engineering, that a national membership committee is set up to direct new membership activities. You are not informed, and probably do not know, that a great many members are organized and give freely of their time toward building the membership of the Institute both in quality and in numbers within their own Sections. These men are the ones who do the real work of contacting nonmembers directly and thereby become "representatives" of the Institute among nonmember engineers. To inform the membership of the scope of this activity and to acquaint the membership of each Section with the names of its members who are at work on this assignment, the personnel of all Section membership committees for the year 1939–40 is printed on this and the facing page.

L. L. Webb

CHAIRMAN, NATIONAL MEMBERSHIP COMMITTEE

Membership

Recommended for Transfer

The board of examiners, at its meeting on December 21, 1939, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Eddy, W. N., director of electrical research laboratory, Simplex Wire and Cable Company, Cambridge, Mass.
Schoolfield, H. H., chief engineer, Pacific Power and Light Company, Portland, Ore.
Yerkes, E. P., engineer of equipment and buildings, Bell Telephone Company of Pennsylvania, Philadelphia.

3 to Grade of Fellow

To Grade of Member

Barnes, W. A., chief engineer, Dominion Electric Manufacturing Company, Mansfield, Ohio.
Hadley, H. L., electrical engineer and estimator, Allis Chalmers Manufacturing Company, West Allis, Wis.
Harkins, P. S., engineer of outside plant, The Bell Telephone Company of Pennsylvania, Philadelphia.
MacKinnon, W. J., assistant electrical superintendent, Pato Consolidated Gold Dredging, Ltd., Pato, Antioquia, Colombia, S. A.
Nelson, L. A., sales engineer, General Electric Company, New York, N. Y.
Travis, I., assistant professor, University of Pennsylvania, Philadelphia.

6 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before January 31, 1940, or March 31, 1940, if the applicant resides outside of the United States or Canada.

United States and Canada

1. North Eastern

Cayey, E. V., Westinghouse Electric and Manufacturing Company, Buffalo, N. Y.
Cook, L. W., General Electric Company, Bridgeport, Conn.
Corbett, V. P., Westinghouse Electric and Manufacturing Company, Buffalo, N. Y.
Garner, G. L., Southern New England Telephone Company, New Haven, Conn.
Hodge, T., Sr., Eastman Kodak Company, Rochester, N. Y.
MacIntire, H. L., Buffalo Niagara Electric Corporation, North Tonawanda, N. Y.
Sheldon, E. E., General Electric Company, Bridgeport, Conn.
Zollin, A. E., Southern New England Telephone Company, New Haven, Conn.

2. Middle Eastern

Baker, F. E., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Barto, J. W., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Batten, R. A., W. V. Pangborne and Company, Inc., Philadelphia, Pa.
Bowden, C. S. (Member), Ohio Public Service Company, Alliance.
Brannan, A. I., Ohio Edison Company, Akron.
Coffin, L. H., Cincinnati Gas and Electric Company, Cincinnati, Ohio.
Delaney, J. J., War Department, Washington, D. C.
Garn, W. B., Westinghouse Transformer Works, Sharon, Pa.
Hager, G. Y., Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Halberstadt, R. L., Bell Telephone Company of Pennsylvania, Philadelphia.
Hoover, C. (Member), Ohio Public Service Company, Sandusky.
Hutcheson, J. P., Jr., care of J. Parks Hutcheson Company, Cleveland, Ohio.
James, W. G. (Member), Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Kroeger, E., 347 East Montana Street, Philadelphia, Pa.
MacDougal, H. M., Copper Wire Engineering Association, Washington, D. C.
Martin, H. S., Fidelity Electric Company, Lancaster, Pa.
Miller, W. W. (Member), Bell Telephone Company of Pennsylvania, Philadelphia.
Myhre, C. B. (Member), Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Nichols, J. J., Bell Telephone Company of Pennsylvania, Philadelphia.
Romero, R. F., Federal Power Commission, Washington, D. C.
Ruch, E. A., Jr., Public Service Electric and Gas Company, Trenton, N. J.
Ryder, G. C., Public Service Electric and Gas Company, Camden, N. J.
Seifried, A. G., B. F. Goodrich Company, Akron, Ohio.
Shank, J. S., United States Patent Office, Washington, D. C.
Yeager, B. J., Cincinnati Gas and Electric Company, Cincinnati, Ohio.

3. New York City

Baker, E. W., American Telephone and Telegraph Company, New York, N. Y.
Collis, R. E. (Member), Bell Telephone Laboratories, New York, N. Y.
Curtis, V. K., Copperweld Steel Company, New York, N. Y.
Dean, W. W., Jr., Jersey Central Power and Light Company, Morristown, N. J.
Erickson, J. R., Bell Telephone Laboratories, New York, N. Y.
Graneto, P. A., Steel and Tubes, Inc., Brooklyn, N. Y.
Hunter, E. A., American Gas and Electric Service Corporation, New York, N. Y.
Irish, J. S., Consolidated Edison Company of New York, Inc., New York, N. Y.
Krzemien, A., Childs Company, New York, N. Y.
Meredith, L. H., Rockefeller Center, Inc., New York, N. Y.
Miller, W. D., Automatic Electric Company, New York, N. Y.
Murphy, H. E., General Electric Company, New York, N. Y.
Ostergren, C. N., American Telephone and Telegraph Company, New York, N. Y.
Reintjes, J. F., Manhattan College, New York, N. Y.
Rowe, J. C. (Member), General Electric Company, Hoboken, N. J.
Schaefer, E. W., Brooklyn Union Gas Company, Brooklyn, N. Y.
Spear, L. Y., Consolidated Edison Company of New York, Inc., New York, N. Y.
Strang, J. G., National Broadcasting Company, Inc., New York, N. Y.
Vogeler, R. A., Cornell Dublier Electric Corporation, South Plainfield, N. J.
Weise, W. P., Consolidated Edison Company of New York, Inc., New York, N. Y.
Weiss, D., Jersey Central Power and Light Company, Allenhurst, N. J.
Zimmerman, C. P., American Gas and Electric Service Corporation, New York, N. Y.

4. Southern

Bowman, J. S., Memphis Light, Gas, and Water Division, Memphis, Tenn.
Boyles, K. W., Commonwealth and Southern Corporation, Birmingham, Ala.
Combs, J. M., Jr. (Member), Mississippi Power and Light Company, Jackson.
Crain, M., Jr., Memphis Light, Gas, and Water Division, Memphis, Tenn.
Deloney, H. L., Louisiana Power and Light Company, Algiers.
Fransioli, W. J., Jr., Memphis Light, Gas, and Water Division, Memphis, Tenn.
Hadsel, H., American Elevator and Machine Company, Louisville, Ky.
Harrison, J. F. (Member), Mississippi Power and Light Company, Jackson.
McNiven, J. A., Louisiana Power and Light Company, Algiers.
Milton, J. C., Mississippi Power and Light Company, Jackson.
Morgan, W. D., Memphis Light, Gas, and Water Division, Memphis, Tenn.
Profilet, W. B., Mississippi Power and Light Company, Jackson.
Sanders, W. F., Carolina Aluminum Company, Badin, N. C.
Wilkerson, C. C., Western Union Telegraph Company, Louisville, Ky.

5. Great Lakes

Anderson, C. G., Schweitzer and Conrad, Inc., Chicago, Ill.
Elliot, W. H., Cutler Hammer Inc., Milwaukee, Wis.
Higgins, T. J. (Member), Purdue University, West Lafayette, Ind.
Keeler, R. J., Commonwealth Edison Company, Chicago, Ill.
Kirk, E. L., Dow Chemical Company, Midland, Mich.
Marshall, R. B., Purdue University, West Lafayette, Ind.
O'Day, J. H., Northwestern Bell Telephone Company, Des Moines, Iowa.
Purdy, R. T., Commonwealth Edison Company, Chicago, Ill.
Trommer, C. H., Public Utility Engineering and Service Corporation, Chicago, Ill.

6. North Central

Landmesser, J. B., 2735 West 20th Avenue, Denver, Colo.
Stuart, E. V., Public Service Company of Colorado Denver.

7. South West

Baltzell, L. A. (Member), Texas New Mexico Utilities Company, Plainview, Tex.
Bostock, G. M., General Electric Company, Dallas, Tex.
Caldwell, R. W., Graybar Electric Company, Inc., Kansas City, Mo.
DeBettencourt, M. A. (Member), 402 Sidney, Houston, Tex.
Keller, E. G. (Member), University of Texas, Austin.
McDougal, I. E., Westinghouse Electric and Manufacturing Company, Wichita, Kans.
Pickens, W. B., Texas Electric Service Company, Eastland.
Reeves, L. P., Southwestern Bell Telephone Company, Tulsa, Okla.
Spreen, H. F., Texas Electric Service Company, Fort Worth.
White, J. B. (Member), International Boundary Commission, El Paso, Tex.
White, M. A., R. H. Reed Engineering Company, Abilene, Kans.

8. Pacific

Ardern, F. V., General Chemical Company, El Segundo, Calif.
Brock, A. E., Pacific Electric Manufacturing Corporation, San Francisco, Calif.
Muller, C. L., Pacific Electric Manufacturing Corporation, San Francisco, Calif.
Ottaway, C. S., Pacific Gas and Electric Company, Oakland, Calif.
Scarfe, S. W. (Member), General Electric Company, Los Angeles, Calif.

9. North West

McCown, J. F., Puget Sound Power and Light Company, Seattle, Wash.

10. Canada

Craik, O. S., Canadian International Paper Company, Gatineau Mills, Quebec.
Macdonald, J. E., British Columbia Electric Railway Company, Vancouver.
Walker, F. L., T. Eaton Company, Toronto, Ont.

Total United States and Canada, 100

Elsewhere

Maile, A. W., Railways Department, Sierra Leone, Freetown, West Africa.
Blackledge, R. S., Messrs. Veritys, Aston, Birmingham, England.

Total elsewhere, 2

Engineering Literature

New Books in the Societies Library

Electrical engineers may be interested in the following new books, which are among those recently received at the Engineering Societies Library, New York, N. Y. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the preface of the book in question.

ÜBERSPANNUNGEN UND ÜBERSPANNUNGSSCHUTZ. (Sammlung Göschen, Band 1132). By G. Frühauf. Berlin, Walter de Gruyeer and Company, 1939. 122 pages, illustrated, 7 by 4 inches, cloth, 1.62 rm. This small work explains overvoltage phenomena and their origin, discusses moving waves and surge voltages, and describes methods and apparatus for the protection of conductors and stations. Impulse processes and impulse testing of electrical windings are also considered.

THE SWITCHGEAR HANDBOOK. Volume 1—Apparatus. Edited by W. A. Coates and H. Pearce. New York and Chicago, Pitman Publishing Corporation, 1939. 190 pages, illustrated, 9 by 6 inches, cloth, $4.50. The joint product of a group of British engineers, each a specialist in the subject he discusses, this book is intended as a general guide to switchgear, considered from the point of view of the user rather than the expert designer. After a discussion of the theory, it considers the actual design of circuit breakers, fuses, switches, instrument transformers, voltage regulators, and other apparatus.